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RECENT AND FOSSIL PEDICELLARIAE

H. L. GEIS

ABSTRACT

The several types of modern echinoid pedicellariae are illustrated and briefly described. Previous reports on fossil pedicellariae are summarized, and illustrations reproduced. Several new fossil forms from Pennsylvanian and Mississippian strata are described and figured; a tridentate form from the Mineral Wells formation of Texas; a tridentate and four globiferous forms from the La Salle cyclothem of Illinois; an ophicephalous pedicellaria from the Graham formation of Texas; and a tridentate and two globiferous forms from five Chester localities in Illinois and Missouri. Dissociated echinoid spines and plates found with the pedicellariae are also figured.

INTRODUCTION

Pedicellariae, their nature, functions, and taxonomic significance, have been the subject of considerable debate among students of modern echinoids. First thought to be parasites, they are now definitely known to be organs of prehension and defense and an integral part of the echinoid. As a consequence of close study by a number of zoologists, pedicellariae are, in spite of their small size, recognized to be important in the specific, generic, or even familial classification of echinoids. Mortensen (1928, 1932), for instance, in several important works on the Cidaridae, has based his classification of the family to a large extent on pedicellariae and has regarded other test features of lesser consequence. Agassiz and Clark (1907) have reversed this emphasis, but nevertheless have granted the pedicellariae a fair degree of importance. Döderlein (1906) expresses moderate views, which accord to pedicellariae an important place in classification but emphasize the necessity of considering all other parts of the body.

Few pedicellariae have been found as fossils. In fact, until 1887, when pedicellariae were discovered by Groom (1887) on the surface of a well-preserved test of *Pelanechinus corallinus* (Wright) from the Jurassic of Great Britain, it had been generally supposed that they were too delicate for preservation. Several other later reports are cited herein, but the records of fossil pedicellariae are so few and incomplete that paleontologists of necessity ignore them in the classification of fossil echinoids.

It now seems probable that the data on fossil pedicellariae are scanty principally because there has been little effort directed toward finding them, and that careful search may yet disclose them in sufficient quantities to give these fossils some taxonomic value. This suggestion is given weight by the recent discovery of several forms of pedicellariae, here described, which occur in some abun-

dance in two zones of the Texas Pennsylvanian, and in one Pennsylvanian and three Mississippian zones of Illinois and Missouri. No complete schinoids have been found, but diseociated plates and spines are common in the shale concentrates. There is good reason to believe that associations of scattered echinoid plates and pedicellariae are of common occurrence in marine shales of the Carboniferous and that the development of a technique of identification based on these fragments will be of both stratigraphic and taxonomic value. The new forms, as suggested below, indicate, for example, that a number of new echinoids belonging to or directly ancestral to groups not previously recognized as occurring in the Paleozoic may be found in the Carboniferous of the Interior Basin.

Acknowledgments.—The research on which this paper was based was conducted in Walker Museum, University of Chicago, under the direction of Carey Croneis, whom I thank for encouragement and helpful suggestions. The Director of the Illinois State Geological Survey kindly authorized the use of samples from which the Chester pedicellariae were obtained. The Texas samples yielding pedicellariae were generously contributed by Mrs. Helen Jeanne Plummer, to whom I am further indebted for several important manuscript corrections. The Illinois Pennsylvanian sample was collected with the aid of Prof. T. E. Savage, University of Illinois, and the correlation was based on field observations made by Dr. J. M. Weller and Dr. H. R. Wanless, Illinois State Geological Survey. I am also deeply indebted to Prof. Hubert Lyman Clark, Harvard University, for several important suggestions, and to Dr. A. H. Clark for a loan of modern echinoids from the U. S. National Museum.

MODERN ECHINOID PEDICELLARIAE

General Description

Pedicellariae occur on almost any part of the outer surface of an echinoid, although any one kind may be confined to either the actinal or abactinal portion, or to some more restricted part of the test, such as the peristome or the genital plates.

An echinoid pedicellaria consists typically of a stalk and a head, which are either in direct contact or are separated by a muscular neck, the whole commonly being covered by epithelium. The stalk may be a single calcareous rod of variable length and variously modified at the ends, or it may be a more or less loosely associated group of calcareous fibers (pl. 58, fig. 14). The proximal end is usually enlarged and is connected by muscles to a small granule on the test (pl. 58, fig. 36). The distal end is enlarged (pl. 58, fig. 19) or contracted (pl. 58, fig. 10), or it may have a distinctly expanded and fragile knot below the distal end. Among the Cidaridae, there may be a subdistal circular collar of spines (pl. 58, fig. 21) called the "limb." A rarer modification of the stalk is found in the Phymosomatidae, which may have two lateral rows of three to five short spines (pl. 58, fig. 19).

Döderlein (1906) finds it possible to divide pedicellariae, on the basis of distal stalk modifications, into two general groups, the cidarid and the diadematid. The first stalk type,

found only in the Cidaridae, has a definitely constricted upper end. In the second type, which occurs among all other families of echinoids, the distal end is unconstricted and commonly may be expanded. In certain groups, such as the globiferous pedicellariae of the Spatangidae, the expansion is subterminal, but the part of the stalk above the swelling is not appreciably thinner than the part below.

The head contains two to five, commonly three, more or less equal calcareous valves, which may be in contact for their entire length when closed (pl. 58, figs. 2, 3), or only at the base, or the base and distal end (pl. 58, fig 10). A conjunctive ligament and a flexor muscle lead from the top of the stalk to the base of each valve, serving to support the head and to help open the valves. A diductor muscle is attached to the external face of each valve and passes below the head to the adjacent valve. Strong, striated adductor muscles, three in number, connect opposing faces of adjacent valve apophyses (pl. 58, fig. 13) and by contraction close the valves.

The valve is a single, perforate or solid, calcareous plate, commonly expanded basally, and with a flattened and grooved articular face. The lateral margins of the base typically are provided with strong teeth which help to articulate the valves. Above the base, the valve is commonly constricted into a concave, narrow blade, though the constriction may be wanting, and the valve may be triangular in outline or expanded at the tip. Commonly a distinct median apophysis lies along the inner surface of the valve for a part or all of its length, and serves proximally as a base of attachment of the adductor muscles. The inner, concave face of the blade may contain a calcareous meshwork, which either occurs as a featureless valve thickening or is arranged in the form of reticulations or serrate crests. In triphyllous pedicellariae the lower part of the blade is in some cases cylindrical or funnel-shaped, and the extension of the lateral margins of the valve to join on the inside of the head is called the "cover plate" (pl. 58, figs. 18, 32). Ophicephalous pedicellariae bear articular loops below the base (pl. 58, figs. 33–35).

Although pedicellariae occur abundantly among the asteroids, as well as the echinoids, there is little difficulty in distinguishing them. The pedicellariae of the starfish are always bifid, the two valves either crossing at the base (pl. 58, fig. 29) or articulating on a separate, calcareous, basal plate (pl. 58, fig. 30). Echinoid pedicellariae, on the other hand, usually have three valves, departures from this number being rare, and the bases meet more or less flush (pl. 60, fig. 21) without a separate basal articulating piece. Articulation is accomplished by muscles, by grooves on the inner contact faces of the base, and by interlocking lateral teeth.

Major Types of Pedicellariae

Bases of classification.—Modern pedicellariae are divided by zoolo-

EXPLANATION OF PLATE 58

FIGS. *1*—Tridentate pedicellaria; inner face of single valve from *Dermatodiadema horridum* A. Agassiz (after Agassiz and Clark), ×50. Recent.

2, 3—Four-valved tridentate ("quadridentate") pedicellaria from *Porocidaris variabilis* Agassiz and Clark, ×18. *2*, Side view of closed head and upper end of stalk. *3*, Distal view (after Agassiz and Clark). Recent.

4—Tridentate pedicellaria from *Glyptocidaris crenularis* A. Agassiz: inner face of single valve (after H. L. Clark), ×20. Recent.

5–7—Bifid tridentate pedicellariae from *Porocidaris variabilis* Agassiz and Clark, ×9. *5*, External surface of single valve. *6*, Side view of closed head. *7*, Distal view (after Agassiz and Clark). Recent.

8—Globiferous pedicellaria of *Echinus sphaera* (Forbes); open head, from above, showing valves supporting poison glands (after Geddes and Beddard), ×35. Recent.

9—Globiferous pedicellaria of *Glyptocidaris crenularis* A. Agassiz; distal end of blade with large terminal tooth (after H. L. Clark), ×45. Recent.

10, 11—Tridentate pedicellaria from *Eucidaris thouarsi* (Valentin). *10*, Closed head, showing distal end of stalk and muscles of attachment, ×33. *11*, Side view of single valve, showing dentate margin and serrate blade thickening (after Mortensen), ×45. Recent.

12—Globiferous pedicellaria of *Pseudoboletia indiana* A. Agassiz; inner face of valve with paired terminal teeth (after H. L. Clark), ×45. Recent.

13—Globiferous pedicellaria of *Rhopalocidaris rosea* Mortensen; showing gland chambers with subterminal apertures, and adductor muscles attached to the apophyses (after Mortensen), ×45. Recent.

14—Calcareous fibers composing stalk of *Habrocidaris scutata* Agassiz and Clark (after Agassiz and Clark), ×45. Recent.

15–17—Ophicephalous pedicellaria of *Pourtalesia wandeli* Mortensen. *15*, Side view of valve, ×110. *16*, Inner face valve, ×110. *17*, Complete head on flattened distal end of stalk, ×65 (after Mortensen). Recent.

18—Triphyllous pedicellaria of *Araeosoma bicolor* Agassiz and Clark; inner surface of valve with "cover plate" (after Agassiz and Clark), ×55. Recent.

19—Globiferous pedicellaria from *Glyptocidaris crenularis* A. Agassiz, showing expanded extremity and spined margins of stalk; valves concealed in gland tissue (after H. L. Clark), ×20. Recent.

20—Globiferous pedicellaria from *Sphaerechinus granularis* (Lamarck), showing toothed blade ends and glands on stalk (after Sladen), ×10. Recent.

21, 22—Globiferous pedicellaria of *Eucidaris thouarsi* (Valentin). *21*, Closed head on stalk, showing circular collar of spines called "limb," ×33. *22*, Inner face of single valve, ×45 (after Mortensen). Recent.

23, 24—Small globiferous pedicellaria of *Tretocidaris spinosa* Mortensen. *23*, Closed head on stalk, ×33. *24*, Side view of single valve showing terminal tooth and subterminal aperature of gland chamber (after Mortensen), ×45. Recent.

25—Triphyllous pedicellaria of *Araeosoma bicolor* Agassiz and Clark; closed head supported by fleshy neck (after Agassiz and Clark), ×55. Recent.

26—Triphyllous pedicellaria of *Echinus sphaera* (Forbes); showing internal musculature and clover-like appearance of opened head (after Geddes and Beddard), ×45. Recent.

27—Triphyllous pedicellaria of *Glyptocidaris crenularis* A. Agassiz; inner face of "leaf-like" valve with bifurcating apophysis (after H. L. Clark), ×45. Recent.

28—Ophicephalous pedicallaria of *Echinus sphaera* (Forbes); section of closed head just above base, showing adductor muscles (after Geddes and Beddard), ×45. Recent.

29—Pedicellaria of the starfish *Uraster glacialis;* closed head with crossed valves (after Herapath), ×175. Recent.

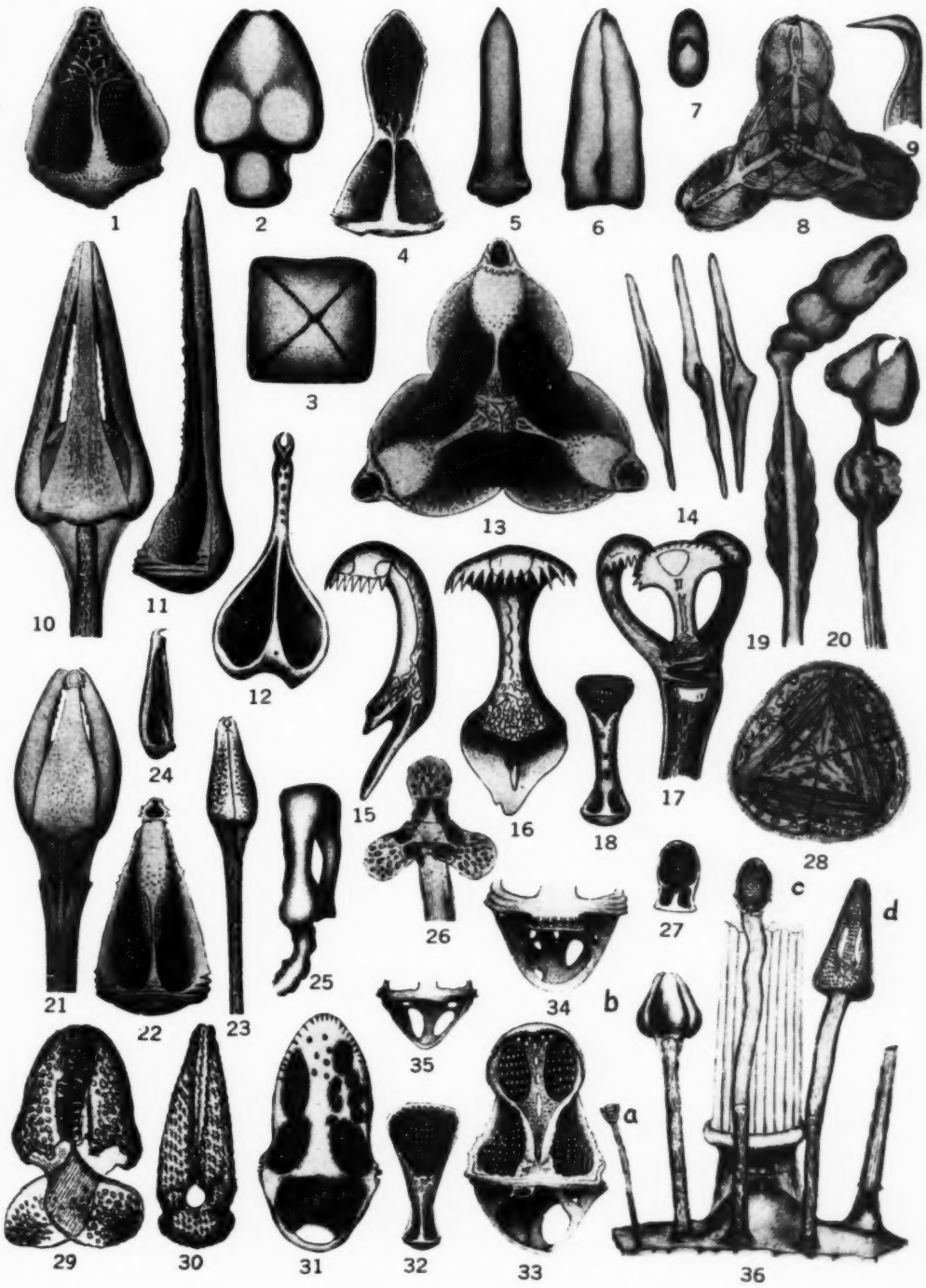
30—Pedicellaria of the starfish *Uraster rubens* (Forbes); closed head with two valves articulating on a separate basal plate (after Herapath), ×175. Recent.

31—Ophicephalous pedicellaria of *Echinus sphaera* (Forbes); inner face of valve with articular loop and lateral articulating teeth (after Geddes and Beddard), ×45. Recent.

32—Triphyllous pedicellaria of *Aspidodiadema tonsum* A. Agassiz; inner surface of valve with "cover plate" (after Agassiz and Clark), ×55. Recent.

33–35—Ophicephalous pedicellariae of *Arbacia dufresnii* Gray, ×55. *33*, Inner face of largest valve with articular loop below articular face. *34*, Base and articular loop of intermediate valve. *35*, Same of smallest valve (after Agassiz and Clark). Recent.

36—Plate, spines, and pedicellariae of *Echinus sphaera* (Forbes); *a*, triphyllous pedicellaria; *b*, globiferous pedicellaria; *c*, ophicephalous pedicellaria; *d*, tridentate pedicellaria (after Geddes and Beddard), ×20. Recent.



Geis, Modern Echinoid Pedicellariae

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gists, with more or less unanimity, into four major types: (1) globiferous, (2) tridentate, (3) ophicephalous, and (4) triphyllous. Two other forms which do not fit conveniently into the above groups, the rostrate and the dactylous, are of such limited occurrence that they are seldom included in general discussions of pedicellariae. As they occur in the several families, the four major types are amenable to further subdivision, with some intergradation. According to Agassiz and Clark (1907) globiferous pedicellariae are distinguished as large or small in the Cidaridae, and as open, fenestrate, or closed in the Echinidae. Tridentate forms may be typical (three-valved), bifid, or quadrate in the Cidaridae and Salenidae; slender or stout in the Diadematidae and Aspidodiadematidae; and involute, contiguous, or convergent in the Echinothuridae. Ophicephalous pedicellariae are ovoid or globose in the Salenidae, whereas in the Diadematidae they may be glandular, non-glandular, or claviform, and in the Pedinidae and Echinidae they may be wide or constricted. The most significant variant in the triphyllous form is the cover plate. The names of the subtypes listed above seem not to be in general use. Döderlein gives another classification based in general upon the names of the families of which the subtypes are most typical.

Of the four major types, any two or more may be found on the individuals of a species, and as many as seven of the variations of these types may occur on a single individual. On the other hand, any of the forms commonly found in the family or genus may be rare or wanting in some species, or even in the individual, in contrast to the usual occurrence in the species. In many species tridentate and globiferous pedicellariae are supplementary in abundance, the one being rare or wanting if the other is abundantly represented.

The division of pedicellariae into the four major types cited above is an unnatural one, and, although probably the best that can be devised at present, it is justifiable only as a convenient means of distinguishing the variations found in the individual or group. More or less complete intergradation is common, particularly between the tridentate, ophicephalous, and triphyllous types. The articular loop, which is most characteristic of ophicephalous pedicellariae, may be found with inferior development on the tridentate and triphyllous forms. The mucous or poison glands, so well displayed in globiferous pedicellariae, are also present on some of the ophicephalous forms. Even the cover plate, which distinguishes a common type of triphyllous pedicellaria, occurs, according to Mortensen (1928), on a developmental stage of the cidarid globiferous pedicellaria (Döderlein's *korbiförmige* pedicellaria). The difficulty of distinguishing between the types is further intensified for the paleontologist by the absence, in the fossils, of such diagnostic soft parts as mucous glands, and by the difficulty

or actual impossibility of separating the valves of a complete head to examine the internal characters.

Tridentate pedicellariae (pl. 58, figs. 1–7, 10, 11).—Tridentate forms of the Cidaridae are in general large, elongate, and conical, without mucous or poison glands. They are

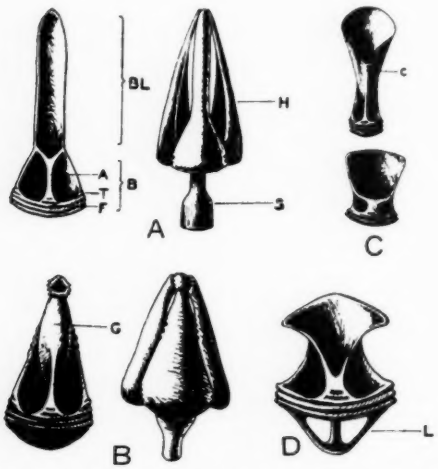

FIG. 1—*A*, Diagramatically presented single valve and complete head of a tridentate pedicellaria, with distal end of a stalk of the cidarid type. A, Apophysis; B, base; BL, blade; F, articular face; H, head; S, stem; T, lateral articulating teeth. *B*, Idealized sketch of a single valve and a complete head of a cidarid type of globiferous pedicellaria; G, poison gland chamber, with subterminal aperture. *C*, Idealized sketches of the two main forms of triphyllous pedicellariaea; c, cover plate: merely the inner surface of the conical blade. *D*, Single valve of an idealized ophicephalous pedicellaria; L, articular loop.

usually three-valved, but may be regularly bifid in *Porocidaris purpurata* Thompson, and quadridentate in *P. variabilis* Agassiz and Clark. Döderlein has reported in another family, the Salenidae, a species with five-valved tridentate pedicellariae.

The valves are elongated, flat or contracted abruptly into a slender blade, smooth or hooked at the end, perforate, and in some species partly filled with a calcareous meshwork, which may take the form of irregular, serrate crests. The valves may be in contact for their entire length, or entirely separated above the base. The base bears an apophysis and is always as wide as or wider than the blade, whereas the blade is as long as or several times longer than the base. The end of the blade, in some families, may be toothed, but the teeth are short. The valves are not covered with thick layers of skin tissue, but appear more or less naked. The size is extremely variable, from 0.5 mm. to 5.0 mm., and the stalk rarely exceeds the length of the head. There is no fleshy neck in pedicellariae of the Cidaridae, but when present on tridentate pedicellariae of other families it commonly varies inversely with the length of the head. This type occurs chiefly among the primary spines of the actinal half of the test, but may also be conspicuous abactinally. Tridentate pedicellariae are found in all genera of echinoids, according to Döderlein (1906).

Tridentate forms of the Arbaciidae are unique in the possession of articular loops, which are equal in the three valves. The valves are attached by a long neck to a slender, distally enlarged stalk, which may be fifteen times as long as the head. Agassiz and Clark report for the Aspidodiadematidae a rare stout

variation, which, because of the absence of a calcareous meshwork and the presence of an articular loop, has been variously designated by other writers as ophicephalous and globiferous.

According to Dëderlein, the tridentate is the basic and parental form from which the other major types have been differentiated. This view is of course deduced entirely from observations of the forms of, and intergradations among, modern pedicellariae, and not upon paleontological grounds. If the tridentate was indeed the ancestral form, it had already yielded at least the full-fledged globiferous type before later Mississippian time, and the ophicephalous by Pennsylvanian time or earlier.

Globiferous pedicellariae (pl. 58, figs. 8, 9, 12, 13, 21–24).—This type commonly bears mucous or poison glands in or on the valves, or on the stalk. The valves generally bear terminal teeth, which may be of considerable length. The head rests directly on the stalk without the aid of a fleshy neck, except in the genus *Strongylocentrotus*. Only the families Salenidae and Arbaciidae, the Clypeastroidea, and the genus *Micropyga* are wanting in globiferous pedicellariae.

It is perhaps questionable that the so-called globiferous pedicellaria of the Cidaridae, which essentially is naked and bears the poison glands internally, should be classed with the remaining forms which bear a voluminous, glandular membrane over the head. However, both forms have the same functions; hence authorities have retained them in the same group.

Variations in globiferous pedicellariae comprise particularly good criteria for distinguishing certain major groups of the echinoids, and for that reason they are most conveniently described in detail under the natural familial groupings.

In the Cidaridae, the head is globular when closed, the valves are large and bear gland chambers. The gland opens distally if a tubular terminal tooth is present, and the subterminal aperture is closed by a layer of ciliated cells. In other species the subterminal opening is partly or wholly devoid of tissue, its margins are irregularly serrate, and the lower margin is marked by an outward curving lip of variable size. The edges of the valve are toothed or crenulate, blunt or pointed distally, and lie in contact with the margins of the adjacent valves for more or less of their entire length. The head is connected directly to the stalk by muscle fibres. The stalk is of variable length, is constricted distally, and may be surrounded by a collar of spicules called the "limb" (pl. 58, fig. 21). Large globiferous pedicellariae measure from 0.5 mm. to 1.0 mm. in valve length and are principally distributed abactinally between the primary spines. The small forms are more slender, the stalk is without a limb, and on any individual echinoid the valves differ from those of the large form in one or more details of structure. The length of the head may be as little as 0.15 mm. The

small globiferous pedicellariae may occur anywhere except in the areolae and the perforate zones of the test and are particularly abundant on the actinal portion. Only in this family do globiferous pedicellariae occur in the buccal area.

The aspidodiadematid form has a globular head, enveloped in a thick membrane, and resting on a short, thick stalk. The valves are commonly triangular and are as wide as they are high. The base comprises most of the valve; the blade typically occupies only the upper end of the triangle and is bent inward distally as a broad, short tooth. Long, sharp teeth do not occur. It is perhaps debatable that this form, occurring only in *Aspidodiadema* and *Dermatodiadema*, is truly a globiferous pedicellaria; poison glands are wanting, but a rather firm, fleshy membrane, always present, indicates the relationship. Accordingly Döberlein does not follow de Meijere in placing it with the tridentate forms, which occur, even in these genera, as essentially naked heads. Neither does Döberlein follow Mortensen in regarding them as ophicephalous, since the absence of an articular loop and the presence of a fleshy membrane are not consistent with that identification. Regardless of their true position, however, they are characteristic of the Aspidodiadematidae.

The echinid form consists of a rather thick stalk or a bundle of calcareous fibers, bearing a fleshy head in which the valves are completely enveloped. Dumb-bell-shaped or bihamate spicules may occur in the tissue surrounding the valves. External poison glands are typical, and a fleshy neck may appear. The base is large, the blade short and sharply constricted into a cylindrical rod, which is commonly characterized by a narrow, open groove along the inner surface and which bears terminal or lateral teeth. The variations in distal dentition afford a good basis for distinguishing several families; the Echinidae bear a single end tooth and lateral teeth; the Echinometridae bear a single terminal tooth and one side tooth; the Taxopneustidae have only the unpaired terminal tooth; the Phymosomatidae possess a single tooth whose length is one-fourth to one-third that of the entire valve; *Hemipedina* has only a pair of end teeth; and *Stomopneustes* and *Centrostephanus* bear several pairs of end teeth and no unpaired teeth. The echinid form is very similar to the globiferous pedicellariae (pl. 60, figs. 14, 15, 22–27) found in the LaSalle cyclothem (Pennsylvanian) of Illinois, suggesting a more complex development of echinoids in the Pennsylvanian than previously has been suspected.

In the spatangid form, the stalk is heavy, with a fragile expansion somewhat below the end, where it breaks easily. The head is enveloped down to the expansion in a thick, stiff, generally dark-colored membrane, by which the valves are completely concealed. The valves are commonly equilaterally triangular in shape, and the base occupies fully the lower half. The funnel-shaped or tubular blade bears terminally a

small mouth, above which large single or unpaired teeth are directed inwardly. The valve is highly convex outwardly. This form occurs in a number of the Spatangidae.

Ophicephalous pedicellariae (pl. 58, figs. 15–17, 28, 31, 33–35).—These forms may or may not have glands. If glands are present, they may occur on the stalk only, or on the head, in which case the valves are reduced or even wanting, as in certain claviform ophicephalous pedicellariae of the Diadematidae. Generally, the head is essentially naked, the valves and stalk strong. The articular loop is characteristically prominent, but usually to a different degree in the three valves, so that the largest tends to overlap the intermediate basally, and the intermediate overlaps the smallest. The valves may be large and ovate in outline, with a coarse reticulation connecting the two lateral margins, or they may be more or less constricted above a large base. Ophicephalous pedicellariae may grade into tridentate forms. This type is completely absent in the Cidaridae, but is present to abundant in the other families.

In the Arbaciidae the median apophysis commonly forks at the base and joins the lateral margins of the blade, as shown in text figure 1D. The stalk is long and flexible, composed of calcareous fibers united only at the ends. Occasionally four-valved ophicephalous pedicellariae are found in the Salenidae and Aspidodiadematidae, and in the latter family articular loops may be equally developed in the valves. In the Diadematidae non-glandular forms are rare; commonly glands are present on the pedicle, and in some species they are present on the head. The ophicephalous pedicellaria of the Echinidae is characterized by a relatively long neck, connecting the head with the club-shaped stalk. The base is large, the blade equidimensional and toothed. Most forms lack the neck, and the head is supported on the flat or concave end of the stalk. Claviform pedicellariae, found in the Aspidodiadematidae and related families, are highly individual. The valves are small and stunted and are enclosed with the thin, solid stalk in a voluminous, sack-like membrane containing three large glands. The diminutive valves resemble the echinid form.

A variation of ophicephalous pedicellaria (pl. 58, figs. 15–17), illustrated by Mortensen (1907) for the Pourtalesiidae, of the Irregularia, is of special interest because of its very close resemblance to an ophicephalous pedicellaria (pl. 59, figs. 28–34) occurring in the Graham formation (Pennsylvanian) of Texas. The stalk is heavy, with an expanded and concave end and with glassy, transparent walls. There is no neck. The head is naked, with a vitreous luster, the blade is cylindrical and is distally expanded and toothed. The articular loop is plate-like in form, being nearly solid. A small pit lies in the terminal blade expansion.

Triphyllous pedicellariae (pl. 58, figs. 18, 25–27, 32).—This type is characterized generally by its very small size, the specimens usually

being less than 0.3 mm. in length. The neck is long, the valves essentially naked. The blade is as broad as, or broader than, the base, the apophysis is reduced. When the cover plate is present (pl. 58, figs. 18, 32), it readily distinguishes triphyllous pedicellariae from all others. More commonly the cover plate is wanting (pl. 58, fig. 27), the valve is short, broad, and flat, a form equally characteristic of this type. If the cover plate is absent, there is normally no calcareous meshwork in the blade, but a short apophysis joins the lateral margins at the proximal end of the blade. The valve may be rounded at the tip or abruptly truncated. Small articular loops, of equal size in each valve, occur in the Arbaciidae, and the triphyllous forms intergrade with the tridentate. They are not found at all in the Cidaridae but are well-represented in most other families. Döderlein states that beyond doubt the triphyllous forms had their origin in the tridentate, from which they are so often difficult to distinguish.

Dactylous pedicellariae ("tetradactyle" of Thompson).—Dactylous pedicellariae, found only in the genus *Araeosoma*, display considerable diversity of form. In some specimens the valves are long and slender, united at the base, and free distally. Other forms have a shorter head, partly or wholly imbedded in tissue. The blade is usually expanded distally.

Rostrate pedicellariae.—This term was used by Mortensen (1907) to designate a pedicellaria found in the irregular echinoids. The head is short, the base quite large, and the blade curved, short, and usually narrow. A row of small teeth lies along the terminal margin. The apophysis commonly bifurcates at the base of the blade.

Functions of Pedicellariae

The functions of pedicellariae have been rather certainly determined by direct observation and experiment. No effort is made here to trace the involved development of thought on the subject, but several of the more reliable and generally accepted observations are summarized.

Sladen (1880) notes that when *Sphaerechinus granularis* (Lamarck) is placed in fresh water, it emits "a glairy mucous matter" over the body in an apparent effort to cloak itself from the unpleasant environment, and that the discharge seems to be secreted entirely by globiferous pedicellariae. He observes further that the echinoids, whose numerous spines should furnish excellent lodgement for various sorts of debris, are nevertheless remarkably clean, a circumstance he explains in the following manner:

> When the tactile cushion of the pedicellaria comes in contact with a tangible object of foreign matter, the valves close, and a discharge of mucous takes place, wherewith the noxious object is covered. When the hold of the jaws is again relaxed, the irritating substance remains entangled in a cloud of glairy exudation, ready to be easily discharged from the surface of the animal by a few movements of the neighboring spines, and is finally carried away by the ordinary currents of water in which the *Echinus* lives.

Sladen's experiments with the starfish *Astropecten aurantiacus*, on which

he scattered fine sand and observed the pedicellariae passing the grains from one to another off the test, justified the conclusion. Tridentate pedicellariae, being without mucous glands, function exclusively in grasping larger bits of exuviae and foreign material and removing them from the shell, whereas triphyllous forms perform a similar service with smaller particles eluding the grasp of the larger organs.

Prouho (1890) conducted a series of experiments in which he was able to observe globiferous pedicellariae in action as defense organs. Specimens of *Asterias alacialis* were starved for some time, then placed in an aquarium with a specimen of *Strongylocentrotus lividus*. When the starfish advanced to attack, the spines of the echinoid were moved away from the spot of impending contact, unmasking the globiferous pedicellariae, which were extended with widely opened jaws toward the starfish. As soon as the approaching arm contacted one of the pedicellaria, the latter closed its valves, and the starfish quickly withdrew its arm, carrying the pedicellaria affixed in its plates. In repetitions of the experiment, the echinoid was overcome only in the event that an unusually prolonged attack depleted it of globiferous pedicellariae.

It seems evident, then, that pedicellariae function both for defending the echinoid against large predatory animals and small parasites and for ridding the test of exuviae and foreign debris.

FOSSIL PEDICELLARIAE

Previous Reports

References to fossil pedicellariae in paleontological and zoological literature are decidely rare. Seven such reports are briefly described below. In six instances the pedicellariae were found preserved on the test and hence were readily identified. Once only were they found loose in a rock sample.

The earliest report of fossil pedicellariae was by Groom (1887), in which he figured three varieties from a well-preserved test of *Pelanechinus corallinus* (Wright), from the Jurassic of Great Britain. The most common variety (pl. 59, figs. 7–9, 11), a tridentate form from the area of the peristome, is not over 1 mm. in length. The head is bluntly conical, and is composed of three closely fitting valves. The valve is broadest at the base, slightly constricted just above it, then expanded into a broad, spoon-shaped blade, the lower end of which contains the upper part of a median apophysis. There are no lateral teeth, and a rounded knob lies on the under surface of each valve. A variant (pl. 59, fig. 10) does not show the basal knobs, but rather the valves are produced to form a stalk facet. A second variety (pl. 59, figs. 4–6), found on the abactinal surface, has a strong triangular base perforated by a circular foramen, and the blade is sharply compressed proximally and expanded distally, with blunt marginal teeth. This form, regarded as tridentate by

Groom, is much larger than the first variety. The third form (pl. 59, fig. 3), which Groom calls "gemmiform," a term now superseded by "globiferous," is smaller, has a shorter base without the circular foramen, and has a very long compressed blade. Numerous specimens occur on the actinal surface of the specimen. Associated stalks are shown in pl. 59, figs. 1, 2.

The second report, by Jackson (1912), lists the only pedicellariae previously described from the Paleozoic. One of the paratypes of *Meekechinus elegans* Jackson, from the Permian of Kansas, bears a number of tridentate (?) pedicellariae (pl. 59, figs. 26, 27). Jackson's outline figures suggest that the head is composed of two valves with decidedly unequal blades. This valve relation is so unusual that I feel justified in questioning the accuracy of the drawings, but since the type specimens of the species seem to have been lost, it is not possible to check on the matter.

Lambert and Thiéry (1909) figure two specimens of a tridentate pedicellaria found on a test of *Miocidaris lorioli* Lambert and Thiéry from the Early Jurassic Hettangien beds of Gammal (Gard). It has a bulbous base and a sharply constricted, long, slender blade (pl. 59, figs. 14, 15).

Lambert (1927) figures a tridentate pedicellaria from a specimen of *Anaulocidaris faurai* Lambert found in the Landinien (Triassic) of Mas

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EXPLANATION OF PLATE 59

FIGS. *1–12*—Pedicellariae and stalks of *Pelanechinus corallinus* (Wright), ×30. *1, 2*, Stalks. *3*, Globiferous pedicellaria, complete head. *4*, Base of large tridentate (?) form. *5*, Distal end of large tridentate (?) head. *6*, Large tridentate (?) head. *7, 8*, Small tridentate pedicellariae. *9*, Internal view of single valve of small tridentate form. *10*, Small tridentate head. *11*, Internal view of single valve of small tridentate form. *12*, Base of small tridentate head (after Groom). Jurassic.

13—Tridentate pedicellaria of *Porocidaris schmideli* (Münster) (after Stefanini), ×?. Eocene.

14, 15—Tridentate pedicellariae of *Miocidaris lorioli* Lambert and Thiéry (after Lambert and Thiéry), ×?. Early Jurassic.

16—Tridentate (?) pedicellaria of *Anaulocidaris faurai* Lambert (after Lambert), ×?. Triassic.

17, 18—Tridentate (?) pedicellaria, species unknown, ×10. *17*, Side view of complete head. *18*, Base of head (after Nielsen). Cretaceous.

19–25—Globiferous pedicellariae, perhaps of *Tylocidaris baltica*, ×10. *19*, Side view of valve. *20*, Basal view of complete head. *21*, Distal end of head. *22*, Side view of head. *23*, Inner face of valve. *24*, External surface of valve. *25*, Inner face of valve (figure 25 after Mortensen, the others after Nielsen). Cretaceous.

26, 27—Tridentate (?) pedicellariae of *Meekechinus elegans* Jackson (after Jackson), ×35. Permian.

28–34—Ophicephalous pedicellariae, ×40. *28*, Exterior of valve. *29–31*, Complete heads. *32, 34*, Interior and exterior of nearly perfect valve. *33*, Interior of valve with blade tip broken off. Graham formation, Texas, Station 202.

35, 36—Echnoid spines. *35*, ×8. *36*, ×18. Graham formation, Texas, Station 202.

37–49—Miscellaneous plates of test and lantern, ×18. *37*, Interambulacral plate, position uncertain. *38*, Half-pyramid from lantern. *39*, Interambulacral plate, perhaps of the Irregularia. *40*, Epiphysis from lantern. *41*, Ambulacral plate from corona. *42*, Interambulacral plate from corona. *43*, Periproctal plate. *44*, Ambulacral plate from buccal area. *45*, Interambulacral plate from corona. *46*, Ambulacral plate from corona. *47*, Periproctal or interambulacral peristomal plate. *48*, Lantern brace. *49*, Interambulacral plate from corona. Graham formation, Texas, Station 202.

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Monet, which is indented from below, has a wide base, and is drawn out distally into a long, compressed blade (pl. 59, fig. 16). In the original figure the orientation is reversed. In discussing this figure, Mortensen suggests that the blade tip has been broken off.

Loose specimens of three-valved pedicellariae, called tridentate by the author, are reported by Nielsen (1925). A complete head (pl. 59, figs. 20–22) from the Skrivekridt (Cretaceous) of Stevens Klint, Denmark, is very short, triangular in cross section, with the blade reduced to a stubby node. The outer surface of the valve is vertically ribbed, and a strong depression occupies the base of the closed head. Single valves (pl. 59, figs. 19, 23, 24) from the same locality have a slightly longer blade, and the base bears a median apophysis. Mortensen considers these pedicellariae to be globiferous rather than tridentate, having found in the blade (pl. 59, fig. 25) a vertical slit, apparently the mouth of an internal gland chamber. When Nielsen first reported the form he gave no indication of the species to which it might belong, but has since concluded tentatively, because of the common occurrence in the same beds of *Tylocidaris baltica*, that it probably belongs to that species. There occurs on the upper portion of the test of *Tylocidaris baltica*, among the secondary spine bases, shallow depressions similar to those seating globiferous pedicellariae in *Goniocidaris* and *Steriocidaris*. Mortensen cites this fact in support of his decision that the pedicellariae described by Nielsen are globiferous.

A complete head figured by Nielsen from the Bryozoakalk of Herfogle (pl. 59, figs. 17, 18) is smaller, has a circular basal section, and a long, slender blade. Mortensen states that the ends of the valves are evidently broken off, and that the complete head probably resembled those of *Steriocidaris sceptriferoides* var. *lanceolata*.

Stefanini (1921) illustrates a tridentate pedicellaria (pl. 59, fig. 13) from *Porocidaris schmideli* (Munster) in the middle Eocene of Italy. It is an outline figure only and gives little information about the form.

Clark and Arnold (1927) report having found both globiferous and tridentate pedicellariae, which they say very closely resemble those of the modern *Eucidaris tribuloides*, on a specimen of *Cidaris gymnozona* Clark and Arnold, from the Tertiary of Jamaica. The pedicellariae are neither described in detail nor figured.

New Fossil Pedicellariae

The fossil pedicellariae here described from the Pennsylvanian and Mississippian strata of Texas, Illinois, and Missouri, are the oldest so far recorded. The next oldest, as noted above, were reported by Jackson from the Permian of Kansas. All others were found in Mesozoic or younger strata. Further, all previously described fossil pedicellariae have been identified with more or less certainty as tridentate or globiferous. Three types, tridentate, globiferous,

and ophicephalous, are described below. Triphyllous forms are not yet known as fossils, probably because their extremely minute size renders them difficult to identify even under the microscope.

Echinoid plates and spines from most parts of the test and displaying considerable diversity were found in abundance associated with the Carboniferous pedicellariae but were always dissociated. Accordingly, it is impossible to determine which of the plates, spines, and pedicellariae are specifically related, except by rather uncertain inference.

Tridentate pedicellariae, Mineral Wells formation, Texas.—A form of tridentate pedicellaria (pl. 61, figs. 4–9) is found in the upper beds of the Mineral Wells shale on Village Bend of the Brazos River, Texas (see index of localities). The head is small, roughly triangular in outline, and is composed of three valves that are in contact at their margins for most of the length of the head. The base is broad and low and only slightly constricted above into a wide, straight blade, which tapers to a rounded point. The blade is strongly convex outwardly. Slightly inclined grooves are present on the narrow articulating face of the base, and a trace of lateral teeth is discernible. A strong median apophysis extends from the base to a point halfway up the length of the valve, where it bifurcates to join the lateral margins. The longest head measures 0.72 mm. in length

EXPLANATION OF PLATE 60

FIGS. *1–3*—Miscellaneous echinoid plates from corona and lantern, ×18. *1*, Ambulacral peristomal plate. *2*, Half pyramid from lantern. *3*, Keeled tooth plate from lantern. Graham formation, Texas, Station 202.

4–8—Echinoid spines, ×18. Graham formation, Texas, Station 202.

9—Echinoid spine or sphaeridium, ×18. LaSalle cyclothem, Illinois, Station 49.

10—Echinoid spine or pedicellaria stalk, ×18. LaSalle cyclothem, Illinois, Station 49.

11–13—Echinoid spines, ×18. LaSalle cyclothem, Illinois, Station 49.

14, 15—Globiferous pedicellaria, ×25. *14*, Exterior of valve. *15*, Interior of valve. LaSalle cyclothem, Illinois, Station 49.

16–21—Tridentate pedicellariae, ×25. *16*, Exterior of valve. *17*, Interior of same valve, blade clear. *18*, Interior of valve with calcareous blade thickening. *19*, Exterior of same valve. *20*, Side view of nearly complete head. *21*, Basal view of same head. LaSalle cyclothem, Illinois, Station 49.

22–27—Globiferous pedicellariae, ×25. *22*, Interior of valve. *23*, Exterior of same valve. *24*, Interior of valve. *25*, Exterior of same valve. *26*, Exterior of valve. *27*, Interior of same valve. LaSalle cyclothem, Illinois, Station 49.

28, 29—Echinoid plates, ×18. *28*, Periproctal or interambulacral peristomal plate. *29*, Ambulacral plate from corona. LaSalle cyclothem, Illinois, Station 49.

30—Ambulacral plate, perhaps from peristome, ×18. Mineral Wells shale, Texas, Station 47.

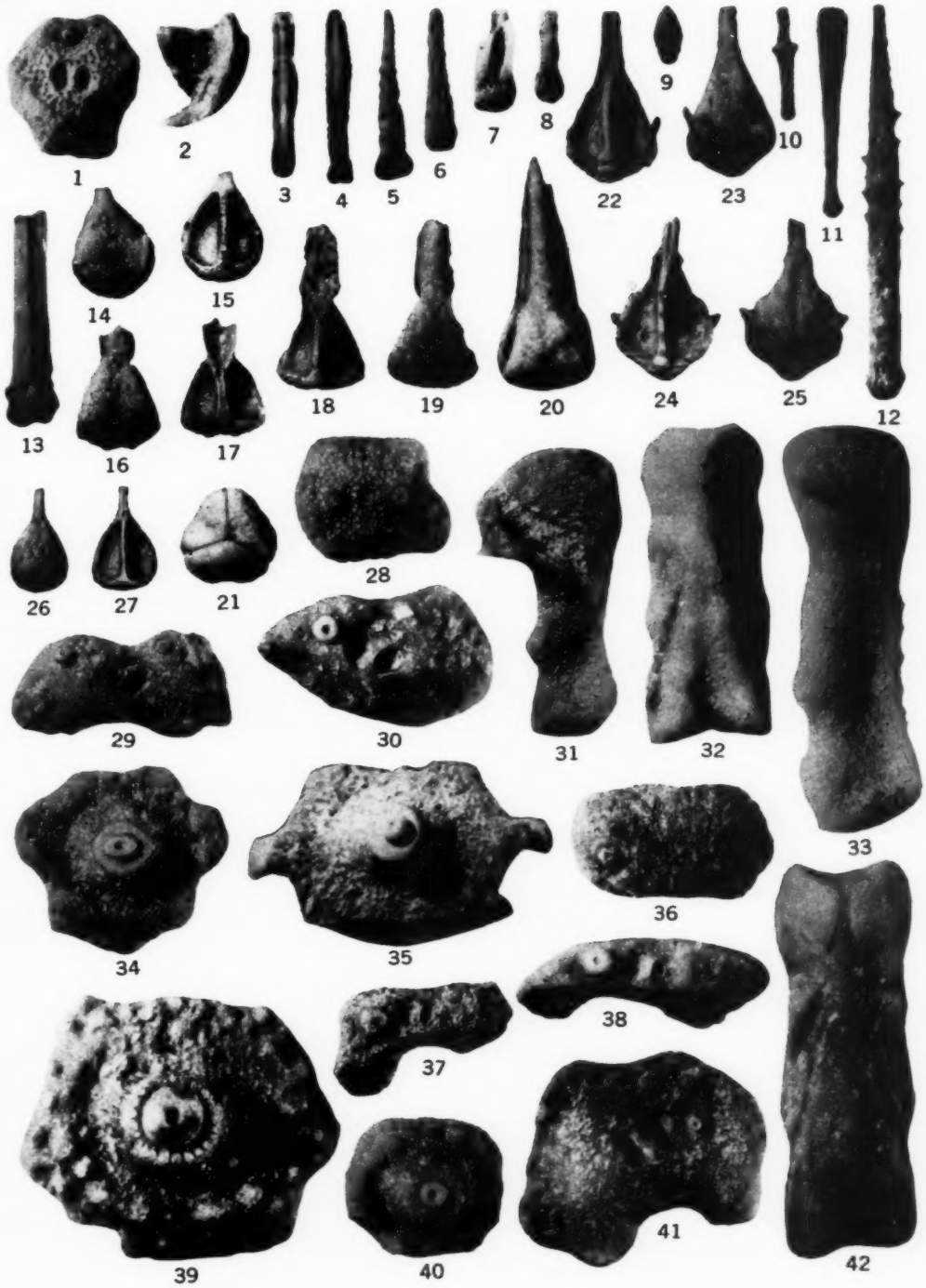
31–33—Echninoid lantern plates, ×18. *31*, Epiphysis. *32*, Brace. *33*, Epiphysis. LaSalle cyclothem, Illinois, Station 49.

34, 35—Echinoid interambulacral plates from corona. *34*, ×18; *35*, ×15. LaSalle cyclothem, Illinois, Station 49.

36–39—Echinoid plates, ×18. *36*, Periproctal or interambulacral peristomal plate. *37–38*, Ambulacral plates from corona. *39*, Interambulacral plate from corona. Mineral Wells shale, Texas, Station 47.

40—Echinoid interambulacral plate from corona, ×18. LaSalle cyclothem, Illinois, Station 49.

41, 42—Echinoid plates, ×18. *41*, Ambulacral plate, perhaps from peristome. *42*, Lantern brace. Mineral Wells shale, Texas, Station 47.



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and 0.45 mm. in maximum basal diameter.

This form is relatively common, nine specimens having been recovered from 2 or 3 cubic centimeters of washed shale concentrate.

Of the associated echinoid remains, two types of archaeocidarid interambulacral plates are common, one with a circular (pl. 60, fig. 39) and the other with an elliptical mamelon (pl. 61, fig. 12). Other small interambulacral, buccal, or apical plates are present (pl. 61, figs. 10, 11), with thinned edges rather than the thickened, nodose edges of the archaeocidarid interambulacrals, and with single, small, eccentric spine tubercles. Ambulacral plates are equally diverse, but all have the distinctly beveled edges characteristic of regular echinoids (pl. 60, figs. 30, 37, 38, 41). The spines, on the whole, are of the type usually found in the Archaeocidaridae (pl. 61, figs. 1–3); but several, resembling those found in other pedicellaria samples (pl. 60, figs. 5, 6) and not illustrated from this locality, are of more uncertain relationships. The pedicellariae are similar in structure to the tridentate pedicellariae of the Cidaridae.

Tridentate and globiferous pedicellariae, LaSalle cyclothem, Illinois.— Two types of pedicellariae, tridentate and globiferous, the latter with several forms, occur in the marine phase of the LaSalle cyclothem in Macoupin County, Illinois. The correlation of these strata (formerly called upper Shoal Creek) with the type LaSalle was made by Dr. J. M. Weller and Dr. H. R. Wanless. The tridentate forms (pl. 60, figs. 16–21) are somewhat similar to those found in the Mineral Wells shale. They have longer, more slender blades, however, and the valves seem not to be in contact along the lateral margins of the base. The articular face is marked by a number of small parallel ridges, which slope downward and outward on each side of the middle. The median apophysis splits and joins the lateral margins at the proximal end of the blade. One specimen (pl. 60, fig. 18) shows a calcareous meshwork in the blade arranged in the form of irregular, serrate crests. Other fragmental single valves (pl. 60, fig. 17) have the inner face of the blade clear. Whether the variation is due to preservation or to specific difference is not certain. The large complete head measures 1.33 mm. in length and 0.57 mm. in maximum diameter.

The globiferous pedicellariae (pl. 60, figs. 14, 15, 22–27), of which there are four variants, are all single valves, and in each specimen the end of the blade is broken off. In one (pl. 60, figs. 24, 25) the base is large and high, tapering to a slender, cylindrical blade with a narrow furrow along its inner side. The lower margin of the valve is obtusely angular. The articular face has one or two inconspicuous horizontal ridges, and the enlarged proximal end of the median apophysis is likewise ornamented with one or more prominent, short articulating nodes. The external surface of the valve bears two long spines, one on each side of the base just above and inside its points

of maximum width. A low ridge runs close to the contact margin of the articular face and joins the bases of the spines. This specimen measures 0.94 mm. in length and 0.54 mm. in width. Another specimen (pl. 60, figs. 22, 23) differs primarily in the outline of the base and in the much less conspicuous external ridge bordering the basal contact margin. The length is 0.94 mm., the width 0.47 mm. A second form (pl. 60, figs. 14, 15) has a distinctly ovate base, and a thick and seemingly ungrooved articular face. External spines are present, but are directed upward rather than outward. The measurements are: length 0.65 mm., width 0.45 mm. A third smaller form (pl. 60, figs. 26, 27) is wanting in the external spines, and the lower outline is flattened. The fourth variation (pl. 61, fig. 28) is represented by a single, complete specimen with a small base and relatively large and long blades, and by unequal valves which overlap ventrally. The internal characters are unknown. This specimen measures 0.57 mm. in length and 0.25 mm. in width. In the absence of mucous glands, it is not definitely demonstrable that the forms here described are actually globiferous. In shape, however, they are very similar to globiferous pedicellariae of the Pedinidae, Echinidae, and related families. If the determination is correct, it is probable that a valve preserved with the blade intact would bear terminal teeth.

Echinoid spines and plates from the LaSalle locality are abundant and well-preserved. Interambulacral plates with elliptical mamelons (pl. 60, fig. 34) do not differ markedly from those of the Mineral Wells shale, but those with rounded mamelons (pl. 60, fig. 35) are rather larger and less nodose at the margins, and possess prominent lateral articulating processes. The ambulacral plates (pl. 60, fig. 29) show marked diversity, but their specific significance is not known. The spines (pl. 60, figs. 11–13) are generally similar to those figured from the Mineral Wells shale. A single spine in the collection (pl. 60, fig. 10) may be a pedicellaria stalk. Several types of lantern plates are common (pl. 60, figs. 31–33). If pedicellariae alone are considered, it seems probable that the assemblage of echinoid remains from the LaSalle cyclothem represents one or more species not present in the Mineral Wells shale sample examined. Tridentate pedicellariae from the two localities present dissimilarities of a magnitude commonly found in different species in modern echinoids. Both, however, are similar to modern cidarid forms. The globiferous specimens, on the other hand, are quite dissimilar to those of the Cidaridae.

Ophicephalous pedicellariae, Graham formation, Texas.—An especially significant form of ophicephalous pedicellaria (pl. 59, figs. 28–34) is found in the Graham formation on Salt Creek one mile west of Graham, Texas. The head is small, and is composed of three subequal valves, which are so curved as to be in contact with each other in the closed head only at the base and distal extremity.

The base is large, inverted triangular in outline. The blade is abruptly constricted and cylindrical at the middle and is expanded distally into a more or less circular end-piece. The lower part of the base supports an articular plate (modified articular loop) which varies in size in the three valves, the smallest being overlapped on one side by the adjacent intermediate plate in the complete head, the largest overlapping the adjacent margins of the intermediate and smallest plates. The articular face is narrow, with one or more longitudinal ridges, and is flanked at the lateral margins of the valve by small teeth, usually poorly preserved. The proximal half of the blade is occupied by a distinct apophysis, the lower part of which is broad and traversely crenulated, the upper part narrow and sharp. The expanded distal blade extremity has toothed lower margins and is marked on the inner side by a central depression. The largest complete head measures 0.5 mm. in length and 0.25 mm. in width. The one complete single valve is 0.43 mm. long and 0.195 mm. wide.

This form is found in the smaller sizes of the washed concentrates of each of four samples from the locality, collected by two persons at different times.

Special interest is attached to the Pennsylvanian ophicephalous pedicellariae because of their very close resemblance to a variety of ophicephalous pedicellaria occurring on the tests of certain modern irregular echinoids, such as *Pourtalesia* (pl. 58, figs. 15–17). It should be stated that Prof. Hubert Lyman Clark considers that the fossil form in question is of very different structure from that of *Pourtalesia* and is more closely allied to ophicephalous pedicellariae of the Pedinidae, as found in the genus *Caenopedina*. A close examination of the illustrations of several species of the two genera, and of actual specimens of *Pourtalesia wandeli* Mortensen, *Caenopedina mirabilis* Mortensen, and *C. hawaiiensis* Clark, has convinced the writer that the Pennsylvanian ophicephalous pedicellariae show a marked resemblance to those of *Pourtalesia* and only a superficial similarity to those of *Caenopedina*. Both the fossil form and the modern irregular type display a plate-like development of the articular loop, a cylindrical development of the lower part of the blade, and a flattened and subcircular development of the distal extremity of the blade, with toothed margins, and a pit on the inner surface. Superficially the resemblance is somewhat lessened by a greater curvature of the valve length in the modern specimens and by a consequent inferior articulation of the upper ends of the valves in the closed head. These, however, are differences of degree and not of kind. In *Caenopedina*, on the contrary, the articular plate is typically looped in all three valves, the median apophysis rises only slightly above the incurved lateral margins of the base and splits above to join the lateral margins of the blade. The blade is deeply concave in cross section, rather than

cylindrical, and the distal expansion, if present, is merely the accompaniment of a flattening of the concavity of the blade rather than a true broadening of it. These are definitely differences of quality and are wide departures from the fossil form. The detail of a more exact contiguity of the ends of the valves in the ophicephalous pedicellaria of *Caenopedina*, and the accompanying ovoid shape of the closed head, as in the fossil form, can not be regarded as significant.

The true significance of the resemblance of the fossil ophicephalous pedicellariae to those of certain irregular echinoids is not fully clear. The evidence of the pedicellariae alone suggests the formerly unsuspected presence of irregular echinoids in the Pennsylvanian. Other possible explanations for the occurrence of the pedicellariae include: the modern and fossil forms are homomorphs and do not indicate a phylogenetic connection; or, the fossil pedicellariae occurred on individuals directly ancestral to irregular echinoids, which did not become otherwise differentiated from the regular echinoids until sometime in the Early Mesozoic. Perhaps a close study of the pedicellariae of the types of *Meekechinus elegans* Jackson, now apparently lost, would yield an answer to this perplexing question.

Another line of evidence bearing on this same subject may be found in the dissociated spines and plates common in concentrates from the Graham locality. The spines (pl. 59, figs. 35, 36; pl. 60, figs. 4–8) are quite varied, but are in general similar to

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EXPLANATION OF PLATE 61

FIGS. *1–3*—Echinoid spines, ×18. Mineral Wells shale, Texas, Station 47.

4–9—Tridentate pedicellariae, ×25. *4, 5*, Exterior and interior views of same valve. *6, 7*, Side view and proximal end of complete head. *8, 9*, Complete heads. Mineral Wells shale, Texas, Station 47.

10–14—Echinoid spine and plates, ×18. *10, 11*, Periproctal or interambulacral plates, position uncertain. *12*, Interambulacral plate from corona. *13*. Half-pyramid from lantern. *14*, Spine. Mineral Wells shale, Texas, Station 47.

15–17—Echinoid spine and plates. *15*, Spine, ×23. *16*, Ambulacral plate from corona, ×23. *17*, Interambulacral plate, position uncertain, ×10. Shelterville member of the Renault formation, Illinois, Station 305.

18–23—Globiferous pedicellariae, closed heads, ×40. *18*, Head from Glen Dean formation, Missouri, Station 26. *19–21*, Proximal and two side views of head from Renault formation, Illinois, Station 307. *22, 23*, Side views of head from the Shetlerville member of the Renault formation, Illinois, Station 305.

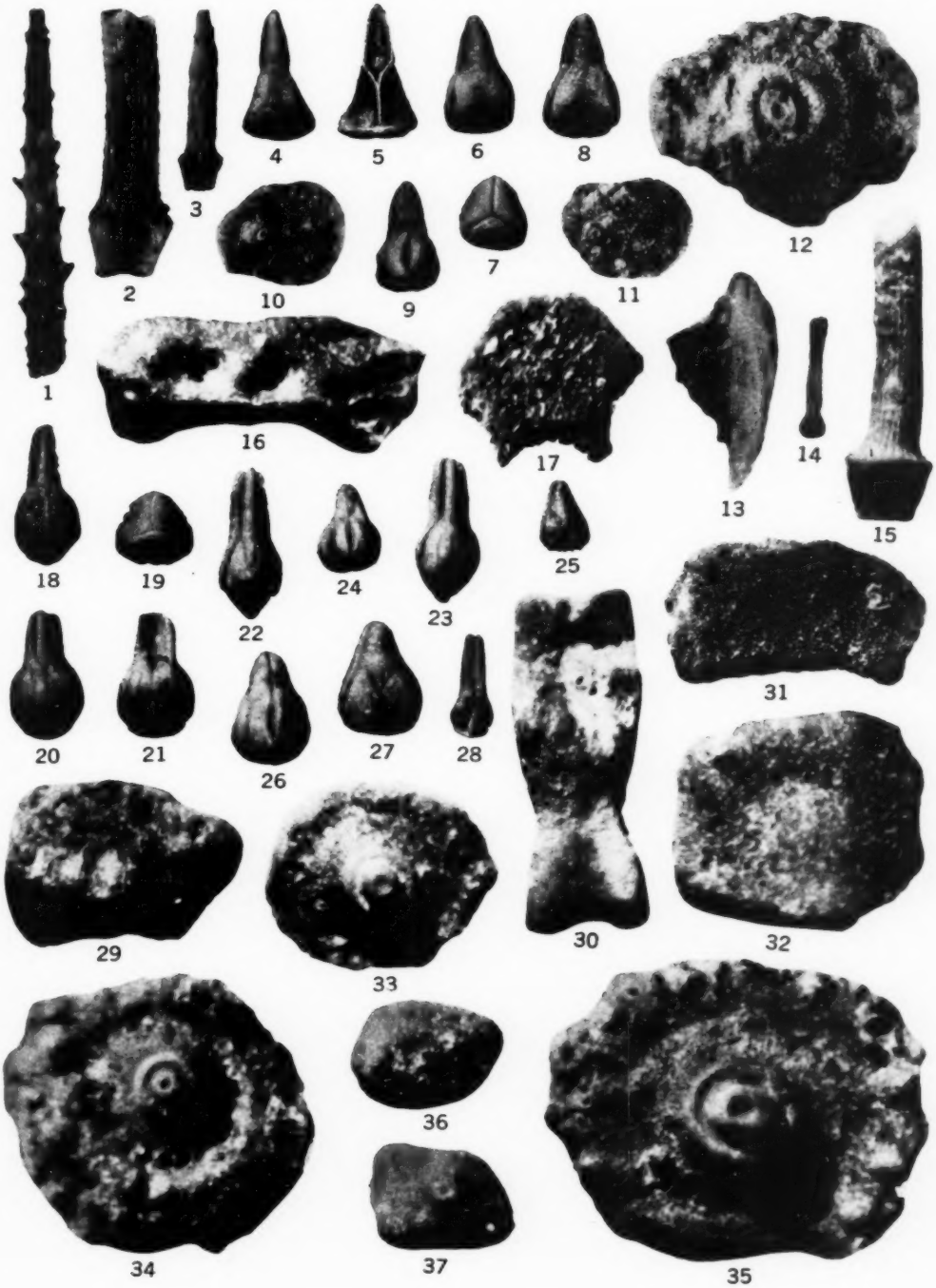
24–27—Tridentate pedicallariae, complete heads, ×40. *24, 25*, Side views of two specimens from the Renault formation, Illinois, Station 304. *26, 27*, Side views of head from Shelterville member of the Renault formation, Illinois, Station 306.

28—Globiferous pedicellaria, closed head, ×25, from the LaSalle cyclothem, Illinois, Station 49.

29—Ambulacral plate from the peristome, ×23. Shetlerville member of the Renault formation, Illinois, Station 305.

30—Lantern brace, ×18. Shetlerville member of the Renault formation, Illinois, Station 305.

31–37—Echinoid plates. *31, 32*, Possibly apical or interambulacral peristomal plates, ×18. *33, 34*, Interambulacral plates from corona, ×23. *35*, Interambulacral plate from corona, ×15. *36, 37*, Apical or interambulacral peristomal plates, ×23. Shetlerville member of the Renault formation, Illinois, Station 305.



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those of the other localities, and the few spines found only in the Graham formation (pl. 59, fig. 36; pl. 60, fig. 8) neither prove nor disprove the presence of irregular echinoids. H. L. Clark in a personal communication suggests that some of the smaller spines might conceivably, but not necessarily, have belonged to specimens of the Irregularia. Of the interambulacral plates, the most common type (pl. 59, figs. 42, 45, 49) is reminiscent of the Archaeocidaridae. A second type (pl. 59, fig. 37), with small spine tubercles and beveled edges, Jackson states in a letter to me, resembles plates found by him on *Pholidocidaris*. A third kind (pl. 59, fig. 39), with numerous closely spaced and equally developed spine tubercles and lacking the beveled edges, resembles plates of the irregular echinoids.

As was suggested to me by A. H. Clark, the fact that irregular echinoids are not found preserved as complete tests in the Paleozoic does not necessarily imply that they were not present. By far the greater number of Irregularia are extremely fragile and would stand little chance of being preserved. It is only in groups now especially characteristic of shallow waters, such as the Clypeasteridae and Scutellidae, that heavy tests are found. Hence we might, *a priori*, expect to find some of the irregular echinoids preserved only as fragments, and thus the tentative interpretation of the Graham ophicephalous pedicellariae as irregular echinoid remains must be regarded as a reasonable suggestion in spite of the non-occurrence of complete tests. Certainly it must be at least conceded, in view of the globiferous and ophicephalous pedicellariae and of the plates herein described and figured, that a greater gamut of diversity is displayed by the echinoids of the Carboniferous than previously has been supposed.

Tridentate and globiferous pedicellariae, Chester group of Illinois and Missouri.—The discovery in the Chester strata in Illinois and Missouri of full-fledged pedicellariae, which would not seem foreign, disregarding preservation, on the tests of modern echinoids, shows the beginning of these unique organs to be still further back in the geologic time scale and leaves their origin quite obscure. Their abundance may be inferred from their occurrence in five of the eight fossiliferous samples casually examined for them.

Pedicellariae of the Chester strata were found only as complete heads, so that only the external characters are known. Nevertheless, the tridentate forms (pl. 61, figs. 24–27) may be identified with reasonable certainty. They occur in the Renault at Station 304, and the Shetlerville member of the Renault formation at Station 306. The tridentate pedicellariae of both localities are quite short, with large, bulbous bases, and short, blunt blades. The valves are in contact throughout the length of the blade and for all but the middle of the base margins. The valves show little evidence of the perforate structure so common in modern forms, and may have been

solid rather than fenestrate. The Chester tridentate forms can not be subdivided, for such differences as appear are within the possible range of specific and subtype variation; but they are notably shorter and more blunt than either of the Pennsylvanian forms. The smallest illustrated specimen measures 0.25 mm. in length and 0.18 mm. in basal diameter; the largest specimen is 0.396 mm. long and 0.28 mm. in diameter.

The pedicellariae here classed as globiferous (pl. 61, figs. 18–23) appear in four Chester localities. The valves are unequal in each, overlapping basally, a feature perhaps more characteristic of ophicephalous forms, but in the absence of single valves it is not known whether articular loops appear. The base is large and furrowed externally, the blade elongate, cylindrical, and sharply set off from the base. Two variations are found: one (pl. 61, figs. 19–21), appearing at Stations 304 and 307, has a large base that is more convex longitudinally (length 0.43 mm., maximum diameter 0.28 mm.); the other (pl. 61, figs. 18, 22, 23), found at Stations 26 and 305, has a smaller and more elongate base, which is more highly convex transversely (length 0.54 mm., maximum diameter 0.23 mm.). The latter variation includes an apparently complete specimen (pl. 61, fig. 23) in which the blade is terminated by a large, inwardly directed tooth. Of the associated spines and test plates, the spines, at least, indicate the presence of several distinct species of echinoids, as yet unidentifiable from the fragmentary remains.

CONCLUSIONS

The full significance to paleontologists of the abundant occurrence of dissociated echinoid pedicellariae in the Carboniferous is yet problematical. Complete echinoids in these strata are generally rare; consequently the taxonomy of the group is not widely or certainly known. Much rarer still is the occurrence of pedicellariae attached to the preserved test. Jackson's (1912) report previously cited, is the only one known to me. There is, further, no prospect that any appreciable number of well-preserved tests with pedicellariae attached will be found. Accordingly, a full taxonomic utilization of fossil pedicellariae must depend upon the development of a technique of identification of echinoid species from their commonly occurring dissociated remains. The difficulties surrounding such a task are obviously considerable but should not be unsurmountable. A close study of large suites of well-preserved fragments should show the possibility of identifying many species from their single plates or associations of separate plates in a given sample, although the possible presence together of several species or genera, and the necessity of inferring specific groupings of plates, spines, and pedicellariae from their repeated association in a number of samples, will leave other identifications in doubt.

Even so, it would seem that a serious study directed along the indi-

cated lines should be profitable. To the extent that Paleozoic pedicellariae can be linked with their respective species, specific identifications will be simplified, and phylogenetic relationships between the groups will be made more clear. The conclusions here presented in the discussions of the various newly described forms, demonstrating the development in the Paleozoic of groups not before known from its strata, and indicating the presence even of the Irregularia, are a case in point.

Another quite promising phase of the study, and one not dependent on a recognition of true specific affinities, involves the unexplored stratigraphic possibilities of pedicellariae alone. It is known from study of modern representatives that they form a sensitive and variable group. Their abundant occurrence in the Pennsylvanian, where accurate index fossils are at a premium, should encourage their study by micropaleontologists.

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Station

26. Glen Dean formation, hard pentremital shale parting, west bank of cut on San

Francisco R. R., 1 mile south of old Red Rock siding, Perry County, Missouri.

47. Mineral Wells shale, Village Bend limestone member, soft, shaly beds of coral reef high on west bank of Village Bend of the Brazos River, Palo Pinto County, Texas (Plummer Sta. 1123).

49. LaSalle cyclothem, shale parting in marine limestone member, near mouth of northwest-flowing ravine, tributary to Macoupin Creek; NW. ¼ NW. ¼ NW. ¼ sec. 36, T. 10 N., R. 7 W., Carlinville quadrangle, Macoupin County, Illinois.

202. Graham formation, hard, rusty shale just below Gunsight limestone member, high on west bank of Salt Creek, about three-quarters of a mile west of Graham, Texas (Plummer Sta. 619).

304. Renault formation, hard, fossiliferous, olive-colored shale; SW. ¼ SW. ¼ sec. 11, T. 12 S., R. 7 E., Hardin County, Illinois (Ill. Geol. Survey loc. 0511.51, P 26 A).

305. Renault formation, Shetlerville member; NW. ¼ SW. ¼ SW. ¼ sec. 26, T. 12 S., R. 7 E., Hardin County, Illinois (Ill. Geol. Survey loc. 0526.52, W K).

306. Renault formation, Shelterville member; NW. ¼ SW. ¼ NE. ¼ sec. 8, T. 13 S., R. 8 E., Hardin County, Illinois (Ill. Geol. Survey loc. 0908.56 A).

307. Renault formation, calcareous, olive-colored shale; SE. ¼ SE. ¼ SW. ¼ sec. 26, T. 12 S., R. 7 E., Hardin County, Illinois (Ill. Geol. Survey loc. 0526.41, P 24 Q).

H. L. GEIS, SHELL PETROLEUM CORPORATION, HOUSTON, TEXAS. MANUSCRIPT ORIGINALLY SUBMITTED APRIL 18, 1935; RESUBMITTED DECEMBER 30, 1935.

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CRETACEOUS ECHINOIDS FROM TRANS-PECOS TEXAS

JEROME S. SMISER

ABSTRACT

This paper describes an extensive collection of echinoids from the Fredericksburg and Washita groups, of Early Cretaceous age, from western Texas. Forty-two species distributed among twenty genera, are described. A new species belonging to each of the following genera are included in the descriptions, *Goniopygus*, *Holectypus*, *Pliotoxaster*, *Macraster*, and *Leiotomaster*. An attempt is made to clarify conclusions which have previously existed within certain Texas Cretaceous echinoid groups. A summary with certain stratigraphic findings is included.

INTRODUCTION

Many of the echinoids described in this paper were collected from localities distributed in a general north-south direction across eastern Trans-Pecos Texas from Fort Stockton on the north to the Rio Grande on the south (fig. 1). They were obtained from rocks belonging to the Fredericksburg and Washita groups of the Comanchean series, of Early Cretaceous age. The Upper Cretaceous rocks examined at numerous places in southern Brewster County failed to produce echinoids.

Some of the most common Texas Cretaceous echinoids, including forms that occur in the Trans-Pecos region, are variously confused in the literature. Since these fossils are common, it is especially important to define clearly their exact specific, generic, and family affinities. This I am here attempting to do, but certain groups which may also need revision are entirely omitted in the present paper, owing largely to lack of adequate material. All of the literature concerning Texas echinoids, together with most of that describing similar and related forms, has been at my disposal. Collections from north-central, south, and west Texas have been used, in addition to type specimens from numerous museums in this country.

Attention will be called in some cases to the fact that certain described Texas Cretaceous echinoids seem to differ in no respect from forms described and figured from geographically distant regions, as, for example, the Cretaceous of Tunis and Algeria and the Cretaceous of Spain and Portugal. The comparisons, however, are based only on study of descriptions and figures of the foreign forms, and if these figures are inaccurate, as I have found in numerous other instances, the conclusions as to close similarity may not be warranted.

Since Roemer (1852) first described echinoids from the Cretaceous of Texas, various writers, most of whom were concerned with entire invertebrate faunas, have described and figured new echinoids from Texas Cretaceous beds. Clark and Twitchell (1915) included the pre-

viously described forms, and added new ones. In recent years Jules Lambert (1926, 1927) and Lambert and Thiéry (1909–25) have redefined, reclassified, and described as new many Texas Cretaceous echinoids.

An earlier paper by me (1933) contains a more complete survey of the literature describing Texas echinoids.

Lambert (1909–25) has published a most comprehensive and elaborate reclassification of the Echinoidea. Although he includes both previously described and new forms of Texas echinoids in this work, he apparently secured much of his data about Texas forms solely from the literature, some of which included numerous inaccurate figures. Subsequently, Lambert (1926) reclassified a large number of forms and described as new species some that had already been figured. This paper was based on a fairly representative group of echinoids furnished him by Prof. Gayle Scott.

Most of the specific descriptions contained in the present paper are made as brief as possible. Usually only the features that actually serve to distinguish the form from its near relatives are included. Most of these forms have been adequately described in previous publications, but the few diagnostic features have not been emphasized adequately. Certain described forms, figures of which are inaccurate, poor or generally inaccessible, are refigured. The one reference listed for each species is not necessarily the original one, but is that which includes a good description and the best available figures.

The classification used is that of Lambert and Thiéry (1909–25).

Acknowledgments.—Thanks are due the Grants-in-Aid Committee of the National Research Council for financial aid in completing the field work. Mr. Henry Fletcher, of Alpine, Texas, has greatly assisted me with his knowledge of the geology of the Big Bend country and by the loan of many echinoids from the Cretaceous of that region. These echinoids, on exhibit at the West Texas Natural History Museum, Sul Ross College, Alpine, Texas, were placed in my hands by Mr. Townsend, of the Museum, who also called attention to certain localities where echinoids were especially abundant and well preserved. Dr. W. L. Moreman, formerly of Texas Christian University, Fort Worth, Texas, has kindly allowed the description of a new echinoid which he collected from the Upper Cretaceous Eagle Ford shale near Langtry, Texas. Dr. W. S. Adkins, formerly of the Texas Bureau of Economic Geology, has been very helpful in advising me on numerous questions connected both with field work and determination of species. Through the Bureau of Economic Geology he also loaned much excellent material for study.

LOCALITIES

Localities 1 and 2.—About 15 miles north of Fort Stockton, just west of the Buenavista Road where there are exposures of the upper part of the Duck Creek, overlain by the Fort Worth limestone and above this the middle cap rock. The alternating limestone and calcareous clay of the upper Duck Creek beds are not yet very fossiliferous and furnished only a few poorly preserved, unidentifiable specimens of *Heteraster*. Some much-weathered specimens of *Macraster* were collected from the Fort Worth beds. One specimen was sufficiently well preserved to be identified as *Macraster subobesus* var. *kentensis* Adkins.

Locality 3.—North Gap at University Mesa, about 17 miles northeast of Fort Stockton,

section 33, block 24, University lands. The Fredericksburg and Washita rocks exposed at University Mesa furnish abundant fossils, including numerous species of echinoids and the fossil zones, marked either by echinoids alone or by associations of echinoids and other fossils, can be seen to advantage. (*a*) The lowest stratigraphic level at which echinoids are found here is near the base of the section in the Fredericksburg limestone, which at this locality is probably the equivalent of the Comanche Peak limestone. Not far above the base of this limestone, which outcrops northward from the mesa, a soft layer furnishes echinoids which mark a zone at this level. The specimens obtainable were too poorly preserved for definite specific determination. The size and general shape of most of the specimens, however, indicate that they probably represent *Heteraster obliquatus* (Clark) and *Heteraster texanus* (Roemer). *Holectypus* sp. aff. *planatus* Roemer is associated with the species of *Heteraster*. (*b*) Another echinoid zone occurs in the clay immediately overlying the Fredericksburg limestone. This zone is marked by abundant, well preserved speci-

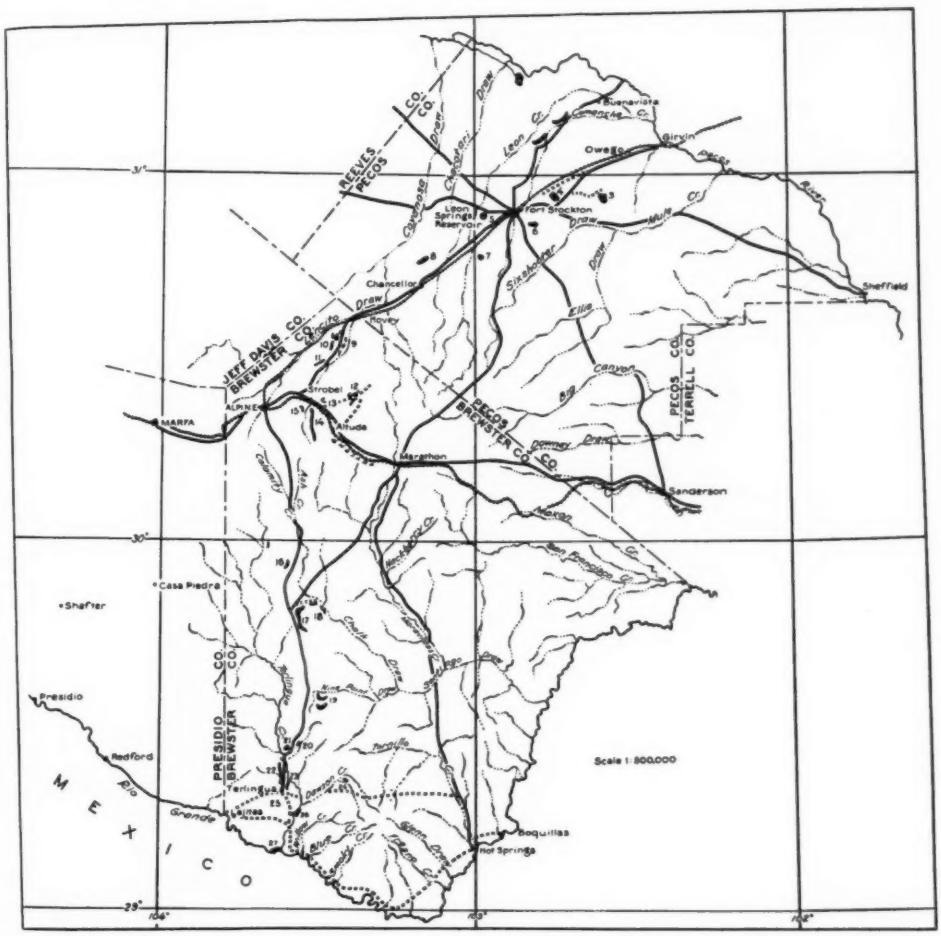

FIG. 1—Localities from which collections were made in eastern Trans-Pecos, Texas.

mens of *Holectypus planatus* Röemer and H. *adkinsi* Smiser, n. sp., together with *Salenia prestensis* Desor, and several species of *Heteraster*, including *H. texanus* (Roemer), *H.* sp. aff. *mexicanus* Cotteau, *H. bravoensis* Böse and *H. adkinsi* Lambert. The echinoids are most abundant about 30 feet above the limestone, and underlie the zone of the fine-ribbed *Oxytropidoceras* that occurs just below the brown *Trigonia* limestone ledge. The association of *Salenia* and *Holectypus* with *Heteraster* is one which is found in the Goodland limestone of north and north-central Texas. This evidence substantiates Adkins' tentative correlation of this 50 feet of clay overlying the Fredericksburg limestone with some part of the Goodland formation. *Dumblea symmetrica* Cragin was collected by Adkins from an horizon below the brown *Trigonia* limestone ledge. (*c*) Above the brown *Trigonia* limestone is another clay extending upward to the Duck Creek *Desmoceras* zone. A few specimens of *Pliotoxaster inflatus* Smiser, n. sp. were collected from this clay. (*d*) Near the top of the Fort Worth formation a very prominent zone characterized by large species of *Macraster* can be seen. This zone contains *M. subobesus* var. *kentensis* Adkins, *M. texanus*, and *M. subobesus*. (*e*) The echinoid zone in the Denton, or middle cap rock, marked by *Pyrina*, *Pseudopyrina*, and rarely *Goniopygus*, so conspicuous at the east end of 7-mile Mesa, was not observed at University Mesa.

Locality 4.—East end of 7-Mile Mesa, about 7 miles northeast of Fort Stockton, west of Girvin road. The section exposed here begins with the Kiamichi clay and extends through the Denton formation. The Fredericksburg portion of the section is not as well exposed as at University Mesa and does not furnish as abundant or as well-preserved fossils. The echinoids collected from the Fredericksburg here include rare and poorly preserved specimens of *Heteraster texanus* (Roemer) and *H. bravoensis* Böse. The clay below the Kiamichi, which ordinarily contains a zone of echinoids, is obscured at this place. (*a*) The upper Washita shows two prominent echinoid zones at 7-Mile Mesa. (*b*) Near the top of the Fort Worth limestone is a *Macraster* zone containing *M. pseudoelegans* and *M. subobesus* var. *kentensis* Adkins. This zone is in a hard, medium-bedded whitish limestone and it is very difficult to secure complete specimens. (*c*) In the lower part of the overlying Denton formation another prominent echinoid zone characterized by *Pyrina* sp. and *Pseudopyrina clarki* (Böse) appears. *Goniopygus stocktonensis* Smiser, n. sp., is found associated with the two genera mentioned but only in the very basal portion of the zone. The latter form is quite rare and was found only at this one locality. The *Pseudopyrina* zone is in a soft layer which has weathered back considerably beyond the harder limestone above and below. The *Goniopygus* occurs in the harder limestone immediately below the receding layer.

Locality 5.—Leon Springs, south of Balmorhea-Stockton road, about 10 miles east of Fort Stockton. The lower Washita, including the Denton, is exposed here with some calcareous shale, below which is probably Fredericksburg. The occurrence of *Heteraster texanus* (Roemer) indicates that this lower part of the section is about equivalent to the upper Fredericksburg of other localities in the area. Associated with the Duck Creek *Pervinquieria* are some very much weathered echinoids which appear to be *Macraster washitae* Lambert. The *Macraster* zone of the Fort Worth and the *Pseudopyrina* zone of the Denton apparently are not present at this locality.

Locality 6.—North side and east end of 5-Mile Mesa, about 5 miles southeast of Fort Stockton. One unindentifiable *Salenia* was obtained from the lower Washita on the north side of the mesa. The Duck Creek is exposed considerably beyond the eastern base of the mesa. From the surface of this outcrop were collected much weathered specimens of *Macraster subobesus* var. *kentensis* Adkins and *M. subobesus* (Adkins) which doubtless had come from the Fort Worth formation and had been transported in some fashion to this point. Since these specimens of *Macraster* were not found in place in the Duck Creek at other localities, it is unlikely that they had come from that formation here.

Locality 7.—West end of 12-Mile Mesa, about 12 miles southwest of Fort Stockton, east of the Alpine Road. An extensive section

from the lowest Fredericksburg (basal sandstone) up to and including the upper cap rock is exposed here. The beds are not as well exposed as at University Mesa, but the section includes practically the same rocks, with a slight thinning of the Washita beds, mostly above the *Desmoceras-Trinodosa* zone. The Fredericksburg is the same as at University Mesa. The echinoid zones, although not prominent, may be observed at the same horizons as for University Mesa. This locality afforded two species not found at University Mesa, but they were not in place and cannot be definitely assigned to any of the known echinoid zones. In float just above the basal Washita a fragment of *Tetragramma streeruwitzi* (Cragin) was collected. This species probably came from the Fort Worth or Denton formations immediately above the place where found. One specimen of *Macraster aguilerae* (Böse) was collected under the same conditions and doubtless came from the Fort Worth formation above, but the Fort Worth did not afford any examples of this species in place.

Locality 8.—Southeast extension of Triple Hill, about 20 miles southwest of Fort Stockton, west of the Alpine road. The base of this section is the upper part of the Fredericksburg. The section is capped by the hard, fine-grained limestone of the middle cap rock. The Kiamichi clay and lower Washita beds are fairly well exposed here. The echinoids present are well preserved, although the number of different species is small. *Heteraster adkinsi* Lambert occurs in the Fredericksburg clay, which here is probably Kiamichi. In the clay above the Kiamichi and extending into the Washita are abundant *Macraster washitae* Lambert. At other localities where the same formations can be seen this species is relatively rare. A number of individuals were found at Loc. 10, but there they were almost wholly confined to the lower Washita. Toward the top of the section, in the lower Denton, *Tetragramma streeruwitzi* occurs but is very rare.

Localities 9 and 10.—About 21 miles northwest of Alpine, east and west respectively of the Alpine-Stockton road. Numerous low hills in this area afford good exposures which combine to give a section from the top of the Fredericksburg limestone through the Denton formation. The zone of *Heteraster*, *Holectypus planatus* Roemer and *Salenia prestensis* Desor may be observed near the base of several of the outcrops. Specimens of *Heteraster* are especially abundant but poorly preserved. Here again the lower Washita strata contain a few *Macraster washitae* Lambert. One specimen of *Phymosoma mexicanum* Böse was collected from the Denton, which caps the section.

Locality 11.—About 15 miles northwest of Alpine, 0.1 mile west of Stockton road. This locality shows a hard, fine-grained, medium-bedded limestone which is similar in lithology to the Fredericksburg limestone. The lower portion of this limestone, exposed along a small creek, contains numerous fossils such as *Engonoceras*, certain gastropods, *Lima*, and *Cyprimeria* which suggest Fredericksburg. Overlying clayey beds yield fragments of *Hamites*, indicating that this portion of the limestone probably represents early Washita time. The uppermost limestone consists of hard flaggy beds. This section shows some of the changing characters of deposition that are exhibited by the northern Fredericksburg and Washita as they pass into the southern or limestone facies characterized by the massive Georgetown-Edwards limestone. Only a few miles north of this place (Locs. 9, 10) the characteristic northern Fredericksburg and Washita appear. A few miles south of Loc. 11, near the Southern Pacific Railroad, the Fredericksburg and Washita are represented entirely by the southern facies. The Georgetown here is less massive than farther south, but the soft limestone and clay, so common in the northern facies, is entirely absent. The massive Georgetown-Edwards beds still contain many types of fossils common to the northern facies, but echinoids are extremely rare and do not again become important until the Del Rio and Buda are encountered, some 50 miles southward, where they overlie the Georgetown-Edwards at numerous places.

Localities 12 to 15.—North and south of Mexican Border Highway between Strobel and Altuda. Loc. 12 and 13 are low hills capped by the Edwards limestone which lies unconformably on the Permian. Fossils are very rare and there are no echinoids. Loc. 14,

south of Strobel, shows a rather complete section of the Georgetown in which some of the Washita formations can still be distinguished rather indefinitely. The rocks here contained no echinoids. Loc. 15 represents a small part of the Upper Cretaceous Eagle Ford and Austin beds which contain no echinoids.

Locality 16.—About 40 miles south of Alpine, 0.75 mile west of the Terlingua road, at Butcherknife Hill. An outcrop of Boquillas flags, preserved because it is on the downthrown side of a fault between this place and Loc. 17. This fault trends east-west bordering the Green Valley on the south-southeast. It extends eastward to Chalk draw and thence southeastward, following the draw, just about to the intersection of the latter with Santiago draw. The westward extension was not traced. The broad alluvium-filled Green Valley offers a few outcrops, but about 8 or 10 miles southward, Loc. 17, upper Georgetown and the overlying Del Rio and Buda are brought up by the above-mentioned fault to a level about 100 feet higher than that of Loc. 16. The Boquillas beds at Loc. 16 contain abundant casts and impressions of several species of *Inoceramus*, but no echinoids.

Locality 17.—About 50 miles south of Alpine, just east of the Terlingua road, across from Buck Hill. The Del Rio clay and overlying Buda limestone are well exposed here. Near the top of the Del Rio is a zone of *Heteraster inflatus* (Cragin), of the small to medium size type mentioned in the descriptions. One large specimen came from an horizon near the top of the Del Rio associated with the smaller individuals. *Hemiaster calvini* Clark appears near the top of the Del Rio, but is most often found in the Buda. The Del Rio also furnishes occasional examples of *Pseudopryina parryi* (Hall) and *Leptarbacia arguta* Clark. The Buda limestone at this locality and farther east contains *Hemiaster calvini* Clark and *Pseudodiadema rotula* (Clark). One specimen of a large, poorly preserved *Heteraster* was found. In size, shape and character of anterior groove this *Heteraster* resembles *H. traski* Whitney and probably represents that species, but the surface is weathered so badly that none of the detail of the ambulacral pores can be studied. In the absence of these details certain identification is impossible.

Locality 18.—A short distance east of Loc. 17 on the west side of Chalk draw. The upper Georgetown is exposed here and underlies the well developed Del Rio and Buda described above. This upper Georgetown furnished only one complete echinoid, *Heteraster wenoensis* (Adkins), and one fragment of a *Holectypus*.

Locality 19.—About 65 miles south of Alpine, 0.5 mile east of road, about 2 miles southwest of Red Bluff. The southern extremity of this outcrop is a southward-facing escarpment of massive Georgetown-Edwards limestone, the lower part obscured by talus from above. Overlying this massive limestone, but cut back considerably northward to form a cuesta face, is the Del Rio clay, capped by the Buda limestone. In float about half way up the massive limestone escarpment a single small *Goniopygus budaensis* Whitney was collected. It undoubtedly came from the upper Georgetown, since the Buda and Del Rio lie too far northward to have contaminated the outcrop. A careful search failed to produce any more echinoids and very few other fossils. The zone of *Heteraster inflatus* (Cragin) marks the top of the Del Rio here, as at Loc. 17, and the echinoid is associated with *Exogyra cartledgi* Böse. The Buda at this outcrop furnished none of its usual echinoid fauna, but the search was not exhaustive.

Locality 20.—Near Abode Walls ranch, 73 miles south of Alpine, east of Terlingua road. An exposure of the Terlingua beds which did not yield any echinoids but contained abundant gastropod casts.

Locality 21.—East of Hen Egg Mountain, 12 miles north of Terlingua on Alpine road and about 75 miles south of Alpine, north of Terlingua road. A southward-facing escarpment of Georgetown-Edwards limestone. Considerable faulting has occurred in the area, and a fault accounts for this escarpment. The only echinoid represented here was *Salenia* cf. *volana* Whitney, of which a rather poor fragment was found. This fragment probably weathered from the Buda and was carried down onto the Georgetown-Edwards outcrop.

Localities 22 to 26.—These localities are all in the vicinity of Terlingua and all failed to

contain any indication of an echinoid fauna. Loc. 22, Boquillas flags and Terlingua beds west of the Alpine road about 2 miles north of Terlingua. Loc. 23, Terlingua beds west of Terlingua Creek, about 1 mile northeast of Terlingua. Loc. 24, an extensive section of Terlingua beds where Cottonwood Creek cuts through the north end of Burro Mesa on west side of Chisos Pen. Loc. 25, Boquillas flags just south of Terlingua on Castelon road. Loc. 26, Terlingua beds on east side of Terlingua Creek, about 5 miles southeast of Terlingua.

Locality 27.—About 15 miles southeast of Terlingua on the Rio Grande at Santa Helena canyon. At this place a fault of great displacement has brought up the Comanchean limestones to the southwest. The Upper Cretaceous series lies to the northeast. The strike of the fault is roughly northeast-southwest. At this point the river flows east and has cut a canyon through about 1,500 feet of these Comanchean limestones. The lower limestones contain the usual fossils found in the Georgetown-Edwards, but no echinoids. The upper limestone were not examined.

SYSTEMATIC DESCRIPTIONS

Class ECHINOIDEA d'Orbigny
Sub-class GNATHOSTOMATA Pomel
Order ENDOCYSTA Lambert
Sub-order STEREOSTOMATA Duncan
Family PHYMATRESIDAE Lambert and Thiéry
Sub-family TIARIDAE Lambert
Tribe PSEUDODIADEMINAE Lambert

Genus PSEUDODIADEMA Desor

PSEUDODIADEMA ROTULA (Clark)

Plate 62, figures 4–6, 10

Cottaldia rotula CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 57, pl. 20, figs. 1*a–d*. —WHITNEY, *1916*, Bull. Am. Paleontology, vol. 26, p. 9, pl. 4, figs. 1–10.

Test small, circular and melon-shaped; upper and lower surfaces flattened unless the apical system is preserved, in which case the center of upper surface is slightly elevated. Ambulacral areas stand out very faintly; ambulacral plates composed of three elements, sometimes with a fourth element consisting of a supplementary demiplate, observed around the ambital region; pore-pairs uniserial, with some tendency toward a biserial character near the peristome, which seems to be an individual variation; ambulacra homogeneous and straight. Interambulacra wide, a little rounded, and supporting numerous tubercles; granules appearing somewhat irregular on casual examination, but shown by detailed study to be arranged very crudely in rows, especially near the apex. Athough tubercles within an area are homogeneous, those of the interambulacral areas are slightly more developed than the ambulacral. On parts of well-preserved, unweathered specimens, such as part of Clark's type, the mamelons on the tubercles are so very conspicuous that they give a very heterogeneous character to the tuberculation. Average specimens show the homogeneous character, however. Tubercles are mammillated, crenulate, and perforate. Average specimens, however, appear either non-crenulate or doubtful, since the delicate crenulations wear off very easily on the fossil forms, and the perforation is sometimes absent or indistinct. Peristome large, with faint branchial incisions. Apical system dicyclic, with large madreporite; opening elongated very slightly anteriorly posteriorly. Unfortunately average specimens do not have the apical system intact.

Occurrence.—Trans-Pecos Texas: Buda limestone, Loc. 17. South Texas: Buda limestone.

Remarks.—This form has been variously classified and confused as a result of the removal of the crenulations, and often the perforations, through weathering. It should, by no means, be confused

with types like cidarids, *Loriolia*, or other forms which have prominent rows of primary tubercles, for in this species the tubercles are all too near the same size for any to stand out very prominently in rows. Whitney's description and figures record correctly the homogeneous tubercles. Clark called the tubercles perforate and non-crenulate, but his type specimen shows them distinctly *perforate and crenulate*. This form can easily be confused with young, small specimens of *Dumblea symmetrica* Cragin, although the latter, in the adult, shows the biserial character for the ambulacral pores, and even younger forms have a wavy to biserial tendency. In fact, I have one specimen from the Fredericksburg at University Mesa which is undoubtedly a very young *Dumblea*, since the pore-pairs are wavy to almost biserial above and biserial below the ambitus. The tubercles do not appear ever to have been crenulate. A practiced eye may often discern the trace of former crenulation on badly weathered material using proper magnification and good light. In general shape this young *Dumblea* is melon-shaped, flat above and below, and on casual examination appears more like the average *P. rotula*.

My observations indicate that *P. rotula* is restricted to the Buda, whereas *D. symmetrica* occurs only in the Fredericksburg and lower Washita beds.

Genus TETRAGRAMMA Agassiz

TETRAGRAMMA STREERUWITZI (Cragin)

Tetragramma streeruwitzi ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 274.

Only one specimen of this rather rare form was obtained, unfortunately with the apical system obliterated. Otherwise the specimen is good and the specific identification can be made with certainty.

The slightly convex form of the test and the distinctly perforate and crenulate tubercles serve to distinguish this species from species of the somewhat

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EXPLANATION OF PLATE 62

Figures natural size, unless otherwise indicated.

FIGS. *1–3*—*Leptarbacia arguta* Clark. Lower view, side view, and upper surface of specimen from Del Rio clay, Loc. 17, 50 miles south of Alpine, Tex. Collection of West Texas Nat. Hist. Mus., Alpine. (p. 457)

4–6, 10—*Pseudodiadema rotula* (Clark). *4*, Upper surface of a specimen showing uniserial ambulacral pores. *5, 6, 10*, Upper surface, lower surface, and profile view of another specimen. Both specimens from Buda limestone, Loc. 17, 50 miles south of Alpine, Tex. Collection of West Texas Nat. Hist. Mus., Alpine. (p. 455)

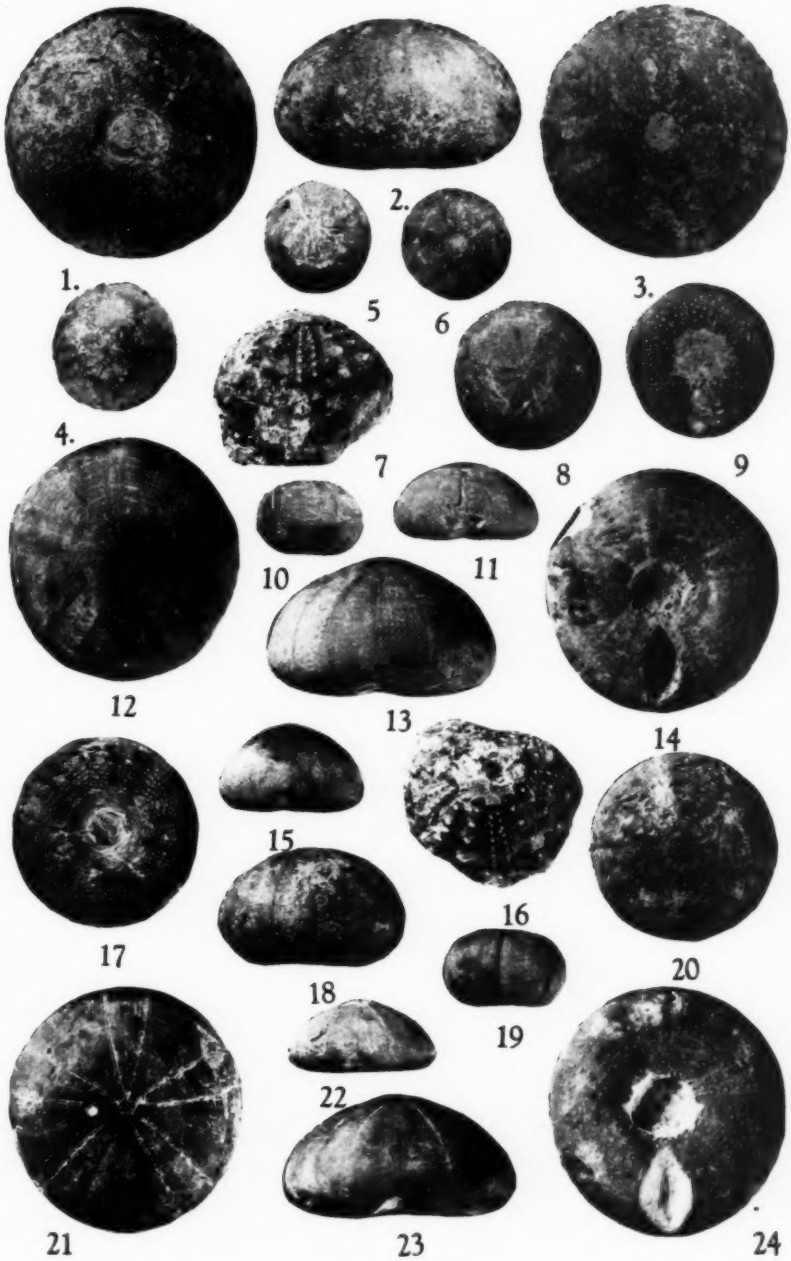
7, 16—*Goniopygus stocktonensis* Smiser, n. sp. Side view, and view showing apical system. Denton formation, Loc. 4, east end 7-Mile Mesa near Fort Stockton, Tex. Figured specimen is the holotype, Smiser Coll., Princeton Univ. (p. 459)

8, 9, 11—*Holectypus planatus* Roemer. Upper surface, lower surface, and posterior view of specimen in Smiser Coll., Princeton Univ. Fredericksburg (Goodland ?) limestone, Loc. 3, University Mesa, near Fort Stockton, Tex. (p. 460)

12–15—*Holectypus adkinsi* Smiser, n. sp. *12–14*, Upper surface, posterior view, and lower surface of the holotype, from Walnut formation, 3.5 miles below Highway 29, Williamson County, Tex. *15*, Posterior view of a smaller specimen, paratype, from Walnut formation, Bull Creek road, northwest of Austin, Tex. Both specimens from collection Bur. Econ. Geology, Austin. (p. 461)

17–20—*Dumblea symmetrica* Cragin. *17, 18, 20*, Lower surface, profile view, and upper surface of specimen from Weno formation, Kent, Tex. *19*, Profile view of a very young individual showing wavy, rather than truly biserial character of ambulacral pores, from Fredericksburg limestone, Loc. 3, University Mesa, near Fort Stockton, Tex. Figured specimens from collection Bur. Econ. Geology, Austin. (p. 457)

21–24—*Holectypus engerrandi* Lambert. *21, 23, 24*, Upper surface, posterior view, and lower surface of specimen from Comanche Peak limestone, at Castle Peak, Taylor County, Tex. *22*, Posterior view of a smaller specimen, of the sort more commonly seen, from the Walnut clay, Bull Creek road, northwest of Austin, Tex. Figured specimens from collection of Bur. Econ. Geology, Austin. (p. 460)



Smiser, Cretaceous Echinoids

UNIV. OF MICH.

similar genus *Phymosoma*. The latter also occurs higher in the Washita of this same region.

Occurrence.—This specimen was not collected in place but on a bench formed by the Fredericksburg limestone, above which outcropped clays and limestones of the upper Fredericksburg and lower Washita. The section was capped by the Denton formation. The specimen doubtless weathered from the lower Washita between the base of the Duck Creek and the top of the Denton. Loc. 8.

Genus LEPTARBACIA Clark

LEPTARBACIA ARGUTA Clark

Plate 62, figures 1–3

Leptarbacia arguta CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 53, pl. 26, fig. 1.

Test medium-sized, circular, tall, distinctly convex above and flattened below, slightly concave around the peristome. Ambulacral plates compound at outer edges, composed of one primary and three demiplates. Pores irregular, tending toward a biserial arrangement. Only one primary tubercle on each ambulacral plate. Interambulacra contain, at the ambitus, six rows of tubercles, the central row of each half area being largest, and only this row persists to the apex. Tubercles of both areas small, crenulate, and perforate. Apical system is small, details obscured. Peristome small and slightly depressed.

Occurrence.—Del Rio clay, Loc. 17.

Sub-family PEDINIDAE Lambert

Tribe CLIMAPEDINAE Lambert

Genus DUMBLEA Cragin

DUMBLEA SYMMETRICA Cragin

Plate 62, figures 17–20

Dumblea symmetrica CRAGIN, *1893*, Geol. Survey Texas, 4th Ann. Rept., p. 150, pl. 34, fig. 12; pl. 25, figs. 4–7; pl. 27, fig. 1.

Test small to medium-sized with flat lower surface and slightly convex to conical upper surface, the adult very similar in general appearance to adult *Leptarbacia arguta* Clark, of which it is possibly the ancestor, as discussed below. Ambulacral and interambulacral areas in adults somewhat rounded, giving specimens a lobed contour. Ambulacra and interambulacra support mammillated, non-crenulate, perforate tubercles. Ambulacral pores biserial, showing this feature very distinctly, even in the smallest young. Ambulacral plates usually three-sociate but may be four-sociate at the ambitus. Apical system dicyclic, posterior right ocular reaching the crudely oval periproct. Peristome medium to large, never small as in *Leptarbacia*.

Occurrence.—Trans-Pecos Texas: Weno at Kent; Fredericksburg at Loc. 3 (a very young form discussed above in relation to its general similarity to *P. rotula*). Adkins lists this species from the Duck Creek, 5 miles southeast of Fort Stockton, as well as from the Weno of north-central Texas, 4 miles southeast of Fort Worth. I have not checked the specimens on which these latter two occurrences are based.

Remarks.—Adkins (1928, p. 276) has called this form *Micropedina*, but its biserial pore-pairs and penetrating ocular and large peristome exclude this genus.

This form may be ancestral to *Leptarbacia arguta* Clark, but I do not have sufficient material to convince me that this conclusion is correct.

Family OLOPHYMIDAE Lambert and Thiéry

Sub-family SALENIDAE Haime

Genus SALENIA Gray

SALENIA PRESTENSIS Desor

Salenia prestensis COTTEAU, *1862–1867*, Paléontologie française, Terrain Crétacé, vol. 7, p. 137, pls. 1032, 1033.

Undoubtedly most of the Fredericksburg and lower Washita salenias of Texas belong to this one species, although there is a great range in size and some slight variations in ornamentation. Cotteau calls attention to these variations. As indicated by Lambert, none of the variations on which *S. texana* Credner and *S. mexicana* Schlüter are based seem to deserve specific names, but are only varieties of *S. prestensis* Desor. Since the

differences can be accounted for entirely by the differing ages of the individuals, the forms collected from the Fredericksburg clay (Goodland) of Trans-Pecos Texas are here described as *S. prestensis* Desor.

Diameter of test, 10 to 20 mm., height 9 to 13 mm. Outline of test circular; flattened below, becoming concave around peristome, but elevated and slightly convex above. Ambulacra slightly sinuous in the smaller forms, becoming more so in the larger. Ambulacral pore-pairs uniserial, mammillated granules separating the two lines of pore-pairs being distinct. Each interambulacrum has 14 plates, 12 of which support one crenulate, imperforate tubercle; plates smaller toward the peristome, with tubercles proportionately decreased in size, and the two plates nearest the apical system supporting no primary tubercles. Only six of the plates are large and contain the six largest of "ambital" tubercles. Periproct subangular with an elevated rim, the highest part formed by the central apical plate. Peristome medium to large and circular, each of the ten interambulacral plates surrounding it cut by one branchial incision. The apical system varies in size with the individual, being proportionately larger in the smaller forms. It is roughly circular and contains, besides the central plate, five genital plates; outside these five ocular plates the right anterior genital carrying the madreporite.

Occurrence.—At University Mesa this species occurs in a zone near the middle of the Fredericksburg clay associated with *Heteraster*, *Holectypus planatus*, *Oxytropidoceras*, and *Engonoceras*. Twenty-one miles northwest of Alpine on the Fort Stockton road the form occurs at the same horizon and is associated with the same fossils. In North Texas this species occurs in the Goodland.

Salenia cf. volana Whitney

Salenia volana Whitney, *1916*, Bull. Am. Paleontology, vol. 26, p. 4, pl. 1, figs. 1–9.

Test circular in outline, with gently convex upper surface and flattened lower surface. Periproct elevated, but much less prominent than in *S. prestensis* Desor. General dimensions very close to those of *S. volana* Whitney.

The two specimens obtained are poorly preserved and the species may not be that described by Whitney.

Occurrence.—One specimen from the lower Buda limestone at Loc. 17, collected by Henry Fletcher of Alpine, Texas. Another specimen was collected by me from float below the Buda limestone outcrop at Loc. 21.

Salenia sp.

A large *Salenia* with practically all details of the test removed. Subcircular in outline, elevated conical upper surface topped by distinctly elevated periproct, flattened to concave lower surface. Peristome medium in size. Diameter about 20 mm., height about 14 mm. The distinctly conical upper surface makes its general profile unlike the other Washita salenias.

Occurrence.—Just below the outcrop of the middle cap rock or Denton formation on the west side of 5-Mile Mesa, Fort Stockton, Texas. Undoubtedly weathered from the middle cap rock.

Sub-family Phymosomidae Lambert

Tribe Coptosominae Lambert

Genus Phymosoma Haime

Phymosoma mexicanum Böse

Phymosoma mexicanum Böse, *1910*, Inst. geol. Mexico, Bol. 25, p. 158, pl. 33, figs, 7–10; pl. 34, fig. 3; pl. 35, figs. 1–3, 7, 8.

Test medium-sized, diameter 38 mm., height 12 mm., distinctly flattened above and below. Pore-pairs of ambulacra biserial above, uniserial below ambitus. Tubercles of interambulacra crenulate and imperforate. Apical system partly obscured but small. Peristome quite large.

The distinctly flattened test, the very large peristome and crenulate but imperforate tubercles serve to distinguish

this form from species of the genus *Tetragamma*.

Occurrence.—From the lower part of the middle cap rock or Denton formation at Loc. 10. Here the form was found distinctly above the horizon of *Pervinquiera trinidosa*.

Family HABROCIDARIDAE Lambert and Thiéry

Sub-family ARBACIDAE Gray

Tribe ACROPELTINAE Lambert and Thiéry

Genus GONIOPYGUS Zittel

GONIOPYGUS STOCKTONENSIS Smiser, n. sp.

Plate 62, figures 7, 16

Goniopygus zitteli CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 52, pl. 14, figs. 3*a–c;* pl. 15, figs. 1*a–h*.

Test subconical and circular in outline with flattened base and elevated upper surface. Ambulacra with uniserial pores crowded toward peristome, and double row of mammillated granules. Interambulacra with two rows of non-crenulate, imperforate tubercles which are very conspicuously developed around the ambitus. Peristome, in so far as can be determined, large, occupying most of the actinal surface. In these specimens all features are like *G. zitteli* except that the genital plates of the apical system are not elongated as in *G. zitteli*, but barely extend beyond the line to which the ocular plates attain. The forms at hand are only partial specimens and some details are lacking. The peristome is partly obscured, but most of the apical system is visible. These rare specimens were collected from a very hard white limestone layer, which rendered extraction of complete specimens practically impossible.

Occurrence.—Lower part of the middle cap rock or Denton formation, just below the *Pyrina* and *Pseudopyrina* zone, at Loc. 4.

GONIOPYGUS BUDAENSIS Whitney

Goniopygus budaensis WHITNEY, *1916*, Bull. Am. Paleontology, vol. 26, p. 6, pl. 2, figs. 1–8.

Test quite small, diameter 5.5 mm., height 3 mm. Circular in outline with convex upper surface and concave lower surface. Ambulacral pores round, porepairs uniserial. Interambulacral areas support mammillated, noncrenulate, imperforate tubercles. Apical system large and prominent, covering most of the abactinal surface, the plates forming a slightly elevated collarette around the periproct. Peristome occupies between one-third and one-half of the lower surface.

Occurrence.—Loc. 19. One specimen collected from float which was definitely derived from the upper Georgetown. Although this form has been described from the Buda, it is impossible that this particular specimen came from the Buda because that formation outcrops back from this scarp on a dip slope.

Order EXOCYSTA Lambert

Sub-order PILAETOIDAE Lambert

Family PYGASTERIDAE Lambert

Sub-family HOLECTYPIDAE Lambert

Genus HOLECTYPUS Desor

The numerous species of this genus represented in both the Fredericksburg and Washita groups of the Texas Comanchean fall naturally into two major groups: (1) species of small to medium size, with periproct occupying nearly the entire actinal face, this group being typically represented by *H. planatus;* (2) species of large size, with periproct occupying one-third to one-half the actinal face, and varying in position (with the species) between the margin of the actinal face and the peristome, this group being typically represented by *H. limitus*.

Small forms of HOLECTYPUS

Some confusion has arisen regarding division into species of the first-mentioned small to medium-sized forms of *Holectypus*. The Texas Cretaceous species are very similar to each other, as well as to foreign species, namely, *H. macropygus* Agassiz and *H. cenomanensis* Gueranger. From a careful comparison of the figures of the foreign with the Texan forms, *H. planatus* seems best viewed as a geographical variety of *H. cenomanensis* Gueranger. Considerable variation is shown by *H. macropygus* Agassiz as figured by different writers. Figures as given by Agassiz (1836–42, pl. 7, figs. 8–11) and Desor (1855–58, pl. 23, figs. 4–6) are exactly alike, but as figured by Cotteau (1862–67, pl. 1015, figs. 1–5) the form is much more elevated and somewhat conical with periproct larger and more rounded at its extremities. As figured by de Loriol (1887–88, pl. 11, figs. 1, 1*a*, 1*b*) the elevation is intermediate, the abactinal surface subconical, and the periproct larger than shown by Agassiz or by Desor, and smaller than shown by Cotteau. The specimen figured by de Loriol more nearly resembles *H. planatus*. This variation in European specimens matches the considerable variation shown by specimens of *H. planatus* from Texas.

The figures of *H. engerrandi* Lambert are very similar to all of these, especially to *H. cenomanensis* Gueranger as figured by de Loriol (1887–1888, pl. 11, figs. 4, 4*a*, 4*b*).

Apparently three species may be recognized among the small to medium-sized Texas forms of *Holectypus*. Two of these might be better interpreted as geographical varieties, but in the absence of the foreign type material for comparison they will have to stand as species. The third is a new species. *H. planus* Giebel is probably a variety of *H. planatus* and is so considered here. In the absence of a figure, Giebel's description is not adequate to separate a form from such extremely similar types. The three species are best separated on the basis of the relation between height and width of the test, the appearance and contour of the upper surface, and to some degree on the width of the periproct as compared with its length. Below are listed the three species with a short review of the diagnostic characters of each.

HOLECTYPUS PLANATUS Roemer

Plate 62, figures 8, 9, 11

Holectypus planatus ROEMER, *1853*, Die Kreidebildungen von Texas und ihre organische Einschlüsse, Bonn, p. 84, pl. 10, figs. 2*a–c*.

Test subpentagonal to circular in outline; depressed, height being 6 to 10 mm.; upper surface evenly and smoothly convex, not at all conical; edge at ambitus thin to medium. Periproct large, asymmetrically oval, pointed at both ends, the inner end coming to a much sharper point.

In this species the height, expressed as a percentage of the width across the widest anterior portion, averages about 47. Roemer's specimen, according to the figure, is 46. The height of the test is on an average less than half the width.

When compared with *H. engerrandi* Lambert or *H. adkinsi* Smiser, n. sp., the test *appears* even less elevated than it actually is by measurement.

Occurrence.—Eastern Trans-Pecos Texas: Fredericksburg clay or Goodland limestone, Locs. 4, 8, 9 and 10. Also widespread in the Goodland of central and north-central Texas.

HOLECTYPUS ENGERRANDI Lambert

Plate 62, figures 21–24

Holectypus engerrandi LAMBERT, *1926*, Soc. géol. France, Bull., vol. 26, p. 269

Lambert based this species on U. S. National Museum specimen 12236A, figured by Clark (1915, pl. 25, figs. 2*a–f*) as *H. planatus*. Clark's figures, as a matter of fact, are highly idealized and

inaccurate. The specimen from which the drawings were made is imperfect, and neither a periproct nor peristome had been uncovered. Clark's fig. 2*b*, showing the periproct, is unquestionably wrong, since the specimen at least does show the inner end of the periproct, which is decidedly pointed. It is well to note that Clark (1893, pl. 23, fig. 2*b*) in an earlier publication figured the periproct correctly.

The test is subpentagonal, the upper surface conical and the edges thin, giving it a "lean" appearance as compared with the "swollen" upper surface of *H. adkinsi*. The elevation is intermediate between *H. planatus* and *H. adkinsi*. The height, as a percentage of the width at widest place, averages about 50, varying from 48 to 51. Clark's figure, which is at least in part a reconstruction, shows a percentage of 48, the lowest figure for any specimen I have examined. The periproct is oval, pointed on inner end and rounded *to a point* on outer end. Shape same as that of the other species but somewhat wider in proportion to its length than in other species. The periproct cuts the margin slightly.

Occurrence.—Eastern Trans-Pecos Texas: Fredericksburg clay or Goodland (?) formation, Locs. 3, 9 and 10, associated with *H. planatus* and *H. adkinsi;* Comanche Peak limestone, Kerr County, 8 miles north of Kerrville on Fredericksburg road, and in Taylor County; Walnut formation, northwest of Austin on Bull Creek road.

HOLECTYPUS ADKINSI Smiser, n. sp.
Plate 62, figures 12–15

Holectypus planatus CLARK, *1915*, U. S. Geol. survey, Mon. 54, pl. 25, figs. 3*a–c*, 4?

Test subpentagonal to pentagonal, elevated and conical, almost pointed with thick edges and "swollen" or fat upper surfaces, as contrasted with the lean *H. engerrandi*. Very tall, the height as a percentage of the width, averaging 58, varying from about 56 to 60. Measurements on Clark's figured specimen show the average of 58. Periproct similar in shape to the other species but cutting the margin of the test more, somewhat as in *H. excisus* de Loriol (1887–1888, pl. 12, figs. 1*a*, *b*, 2).

Occurrence.—Eastern Trans-Pecos Texas: Fredericksburg clay or Goodland (?) formation, Loc. 3, associated with *H. planatus* and *H. engerrandi;* Comanche Peak limestone, Williamson County, San Gabriel River, 3½ miles below Highway 29; Walnut clay (?), southern Somerville County, Horn Pasture; Walnut clay northwest of Austin on Bull Creek road, associated with *H. engerrandi*, and 5 miles northeast of Burnet, associated with *H. engerrandi.*

Large forms of HOLECTYPUS

The group of larger forms of *Holectypus* with small periprocts so far described from Texas includes four species. *H. transpecosensis* Cragin and *H. limitus* Böse are very similar forms and, according to the figures and descriptions, differ mainly in size and in outline. The former is medium to large, pentagonal, with periproct rounded on inner end; the latter medium-sized, nearly circular or subpentagonal, with periproct pointed at both ends. *H. castilloi* Cotteau, described from Texas by me (Smiser, 1933, p. 148), and *H. charltoni* Cragin differ only in that the periproct in *castilloi* is pointed on both ends, whereas *charltoni* has the inner end rounded. I have not seen all of the types and do not have sufficient material on which to decide the validity of these different species, but it is quite probable that some could be combined.

A fragment of a rather large species, probably *H. charltoni* Cragin, was found in the lower Buda at Loc. 18. In the absence of the periproct the fragment cannot be specifically assigned. No other representative of the large-sized Washita species was found in eastern Trans-Pecos Texas.

Family CONULUSIDAE Lambert

Genus PYRINA Desmoulins

PYRINA sp.

Plate 63, figures 2, 3

Genotype, *Pyrina petrocoriensis* DESMOULINS, *1853–1859*, Paléontologie française, Terrain crétacé, tome 6, p. 486, pl. 986, figs. 1–5.

Test subcircular, elevated and conical but neither inflated nor globose as in *Globator* (Sub-class Atelostomata, Family Echinoidae) nor evenly rounded or convex as in *Pseudopyrina* (Family Echinoidae). In general form and size resembles very closely the smaller species of the genus *Holectypus* (Family Pygasteridae), particularly *H. engerrandi*. However, it cannot be confused with the latter species because of the entirely different character of the tuberculation on the test. The edge of the test around the ambitus is thick as in some species of *Holectypus*. Its relation to *Globator* and *Pseudopyrina* is shown in details such as the peculiarly depressed areolae around the tubercles, supermarginal periproct, and the very slightly ovoid form of the large subcircular peristome with longer diameter in a posterior-anterior direction. Periproct obliterated.

The one poorly preserved specimen collected is considerably less tall than any species of *Pyrina* figured in the literature. The condition of the specimen, however, does not permit the establishment of a new species.

Occurrence.—Middle cap rock or Denton formation, Loc. 4, associated with *Globator* and *Pseudopyrina*.

Sub-class ATELOSTOMATA Pomel

Order BRACHYGNATHA Lambert

Sub-order GLOBATORSIDA Lambert

Family ECHINONEIDAE Agassiz

Sub-family DESORELLIDAE Lambert

Tribe GLOBATORINAE Lambert

Genus GLOBATOR Agassiz

GLOBATOR BULLOIDES (Cragin)

Plate 63, figures 20–22

Pseudopyrina? bulloides CRAGIN, *1893*, Geol. Survey Texas, 4th Ann. Rept., p. 162.

Test globose and subconical; basal

EXPLANATION OF PLATE 63

Figures natural size, unless otherwise indicated.

FIGS. *1, 4, 15, 23–25—Pliotoxaster inflatus* Smiser, n. sp. *1, 4, 23, 25*, Upper surface, lower surface, posterior view and profile view of specimen from Kiamichi clay, Loc. 3, University Mesa, near Fort Stockton, Tex., in collection Bur. Econ. Geology, Austin. All views ×0.75. *15*, Upper surface of a fragmental specimen showing pentagonal peristome, from same horizon and locality, ×0.75. *24*, Upper surface of a smaller specimen from same horizon and locality, ×0.75. Specimens shown in figs. *15* and *24* from Smiser Coll., Princeton Univ. (p. 465)

2, 3—Pyrina sp. Profile view and lower surface of specimen from Denton formation, east end of 7-Mile Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 462)

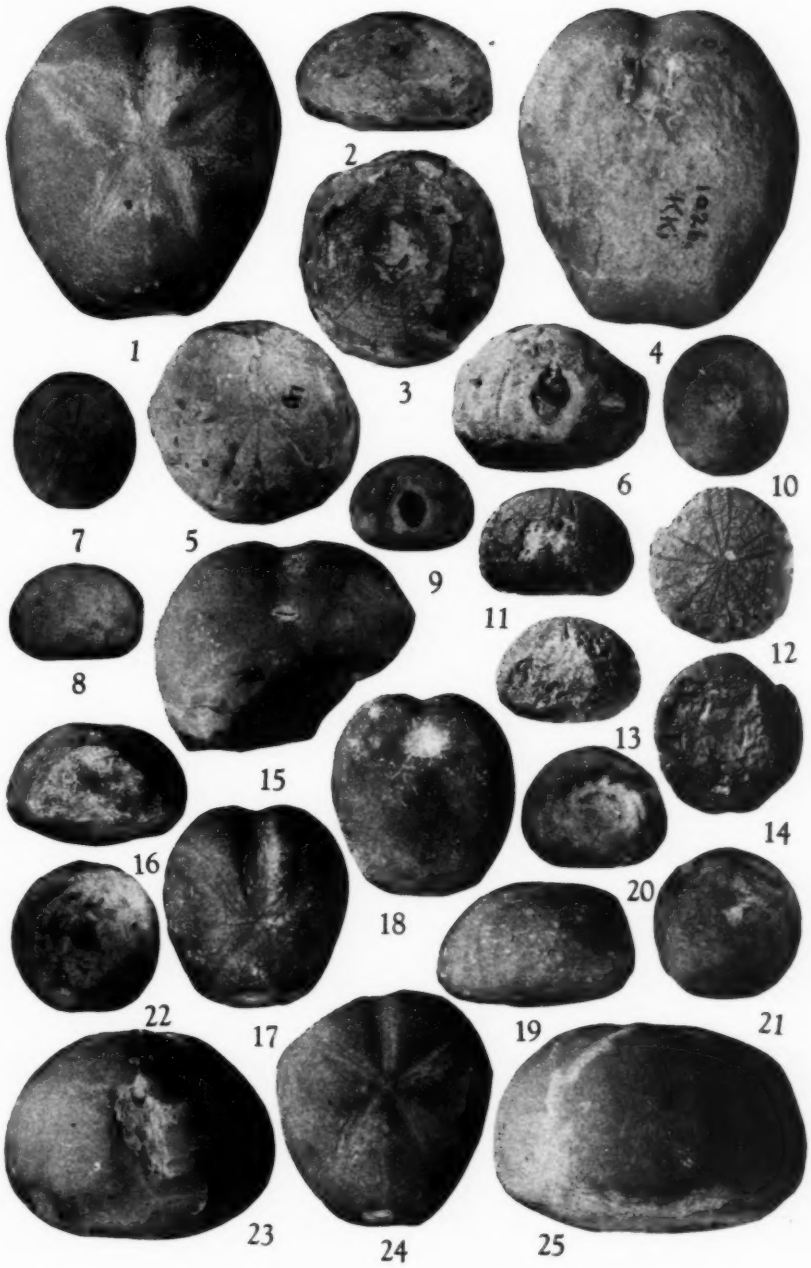
5, 6—Pseudopyrina inaudita (Böse). Upper surface, and posterior view of specimen from Denton formation, east end 7-Mile Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 463)

7–10—Pseudopyrina clarki (Böse). Upper surface, lower surface, profile view, and posterior view of specimen from Denton formation, east end 7-Mile Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 463)

11–14—Pseudopyrina parryi (Hall). Profile view, upper surface, posterior view, and lower surface of specimen from upper Georgetown limestone, Loc. 18, 50 miles south of Alpine, Tex. Collection of West Texas Nat. Hist. Mus., Alpine. (p. 463)

16–19—Heteraster adkinsi Lambert. Posterior view, upper surface, lower surface, and profile view of specimen from Kiamichi clay, Loc. 8, Triple Hill, southwest of Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 468)

20–22—Globator bulloides (Cragin). Profile view, upper surface, and lower surface of specimen from Denton formation, east end of 7-Mile Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 462)



Smiser, Cretaceous Echinoids

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contour almost circular, with no suggestion of pentagonal shape but a slight tendency toward anterior-posterior elongation. Peristome small, located in center of lower surface. Periproct supermarginal, nearly round, the perpendicular axis only slightly longer than the horizontal.

Occurrence.—Middle cap rock or Denton formation at Loc. 4, in soft receding zone near base of formation, associated with *Pyrina* and *Pseudopyrina*.

Sub-genus PSEUDOPYRINA Lambert

Pseudopyrina is ovoid in contour, evenly rounded to conical on upper surface, and flattened on lower surface with distinct peristomial depression. The peristome is slightly anterior to center of lower surface. The periproct is supermarginal, oval, bluntly pointed at top and bottom, and its outline is symmetrical, *not larger at the bottom* as some figures show. Böse's figure of *Pseudopyrina clarki* shows the exact and true shape of the periproct which persists through the various Texas species.

Considerable confusion regarding the classification of *Pyrina*, *Globator*, and *Pseudopyrina* has arisen in the literature on Texas Comanchean forms. Species of *Pseudopyrina* and *Globator* have long been called *Pyrina*, from which they differ considerably. None of the Texas forms heretofore described resemble the genotype *Pyrina pectrocoriensis* Desmoulins. The middle cap rock or Denton formation at Loc. 4 furnished one doubtful representative of *Pyrina*, described here as *Pyrina* sp. One species described, but not figured, by Cragin as *Pseudopyrina? bulloides* is a little like *Pyrina* in that it is elevated and almost conical, but its basal contour is circular to slightly ovoid, rather than circular to slightly pentagonal as in *Pyrina*. *Pseudopyrina? bulloides* Cragin probably belongs to *Globator* Agassiz and has been so considered.

PSEUDOPYRINA INAUDITA (Böse)
Plate 63, figures 5, 6

Pyrina inaudita BÖSE, *1910*, Inst. geol. México, Bol. 25, p. 162, pl. 38, figs. 3–8; pl. 39, figs. 1, 2, 4.

Contour of test nearly circular, evenly rounded on upper surface and not elevated as in *Globator*. Peristome larger in relation to size of the specimen than in other species of *Pseudopyrina*. Periproct large, much larger than any other species of the sub-genus, narrowly oval, and extending from the ambitus to a distinctly supermarginal position.

Occurrence.—Middle cap rock or Denton formation, at Loc. 4, associated with *Pyrina* and *Globator* and other species of *Pseudopyrina*.

PSEUDOPYRINA PARRYI (Hall)
Plate 63, figures 11–14

Pyrina parryi CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 67, pl. 37, figs. 1*a–j*.

Test a short, broad oval, evenly rounded on top. Peristome small, located in the center of lower surface of test. Periproct a narrow, symmetric oval, slightly pointed at both ends and located almost on the line of the ambitus and extending slightly *above* same.

Occurrence.—Middle cap rock or Denton formation at Loc. 4, associated with *Pyrina*, *Globator* and other species of *Pseudopyrina*. Also upper Georgetown limestone at Loc. 18.

PSEUDOPYRINA CLARKI Böse
Plate 63, figures 7–10

Pseudopyrina clarki BÖSE, *1910*, Inst. geol. México, Bol. 25, p. 163, pl. 39, figs. 3, 5–8; pl. 40, figs. 1–3.

Test distinctly oval in outline and convex apically. Peristome small, located anterior to the center of the lower surface of the test. Periproct a narrow, symmetric oval located about the line of the ambitus and extending slightly *below* it.

Occurrence.—Middle cap rock or Denton formation at Loc. 4, associated with *Pyrina*, *Globator* and other species of *Pseudopyrina*.

Order NODOSTOMATA Lambert
Sub-order SPATANGOIDA Agassiz
Family PROSPATANGIDAE
Sub-family TOXASTERIDAE Lambert

The sub-genus *Pliotoxaster* and the genera *Heteraster* and *Washitaster* represent the Prospatangidae in the Texas Comanchean. The forms comprising *Pliotoxaster* have commonly been referred to very similar genera of another family, the Brissidae. The forms which belong to *Pliotoxaster* are distinguished by more superficial or only slightly depressed paired ambulacra and by their more oblong, even straight-sided, shape. *Heteraster* is distinct from all other genera in the Texas Comanchean except *Washitaster*, with which it shows some similarity but insufficient to cause confusion. However, the species of this genus so far described are extremely similar, so much so that between some I can see no differences at all. Furthermore, some seem to be identical with foreign forms previously described, although here again the lack of comparative material makes definite conclusions impossible. In describing species of this genus below, I have attempted to clarify some of the confusion accumulated in specific descriptions. *Washitaster* is unique in that the conspicuously depressed anterior ambulacrum has similar pore-pairs, the pores rounded and separated by a distinct granule. No representatives of this genus were found in Trans-Pecos Texas.

Genus PLIOTOXASTER Fourtau

PLIOTOXASTER WHITEI (Clark)

Plate 65, figures 9, 12, 14, 17, 20

Hemiaster whitei CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 89, pl. 43, figs. 2*a–c;* pl. 44, figs. 1*a–h*.

Test of medium size, low, only slightly convex on upper surface, and less convex to flattened on lower surface; elevation at posterior portion somewhat more than at anterior, giving a slight anterior declivity to the aboral profile; posterior truncation nearly vertical. Carina low

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EXPLANATION OF PLATE 64

Figures natural size, unless otherwise indicated.

FIGS. *1–3, 9, 10—Lambertiaster ficheuri* Dalloni and Lambert. *1, 3, 9, 10*, Lower surface, upper surface, posterior view, and profile view of specimen from Duck Creek limestone, Loc. 10, 21 miles northwest of Alpine, Tex. All figures, ×0.75. *2*, Upper surface of a specimen from Duck Creek limestone of north-central Texas, ×0.75. Both specimens from Smiser Coll., Princeton Univ. (p. 475)

4–8—Leiotomaster bösei Smiser, n. sp. *4, 6, 7, 8*, Profile view, upper surface, posterior view, and lower surface of holotype from Eagle Ford shale, 13 miles south of Del Rio, Tex. *5*, Upper surface of a paratype from Eagle Ford shale, 3 miles east of Langtry, Tex. Both specimens from Smiser Coll., Princeton Univ. (p. 476)

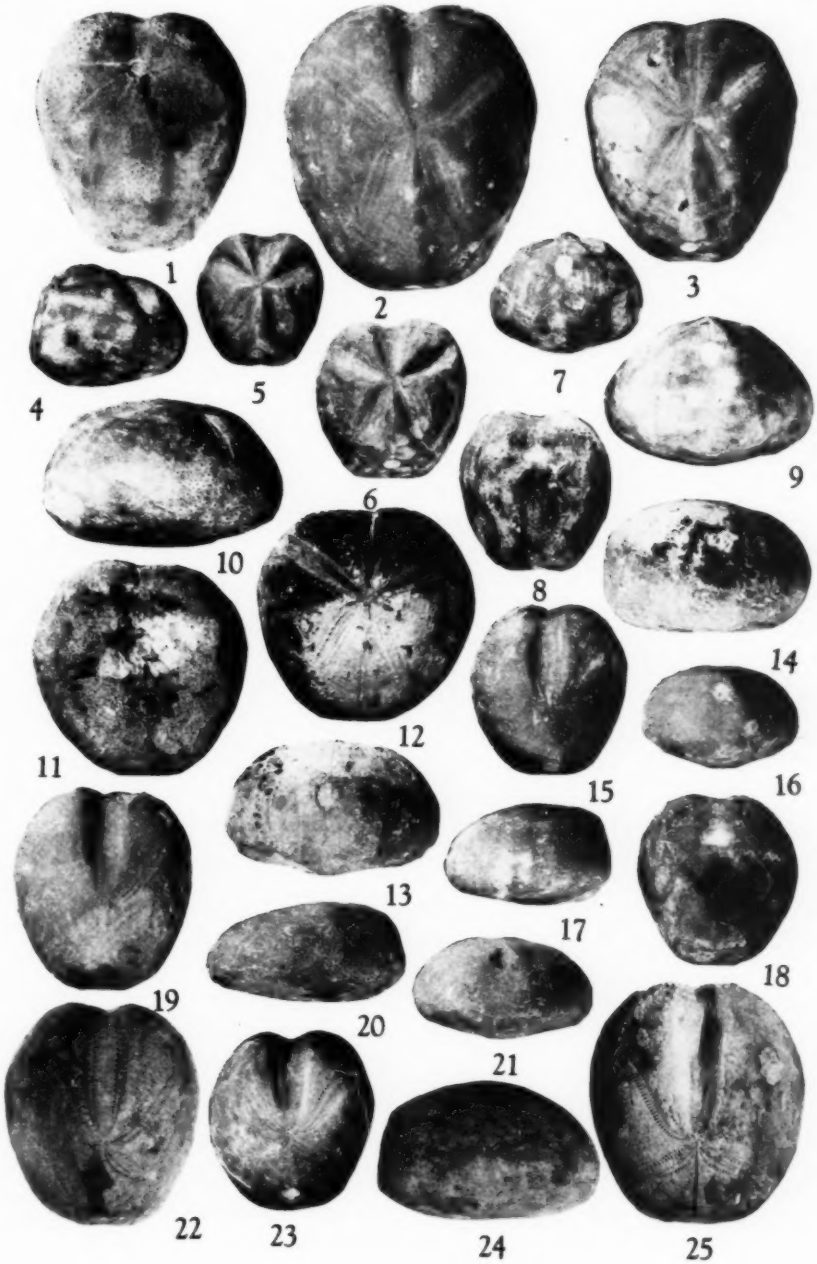
11–14—Macraster roberti var. *ovatus* Smiser, n. var. Lower surface, upper surface, posterior view, and profile view of type from Duck Creek limestone, Loc. 10, 21 miles northwest of Alpine, Tex. Smiser Coll., Princeton Univ. (p. 472)

15–18—Heteraster texasus (d'Orbigny). Upper surface, posterior view, profile view, and lower surface of specimen from Kiamichi clay, Loc. 10, 21 miles northwest of Alpine, Tex. Smiser Coll., Princeton Univ. (p. 468)

19–21—Heteraster mexicanus (Cotteau). Upper surface, profile view, and posterior view of specimen from Kiamichi clay, Loc. 3, University Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 468)

22–24—Heteraster bravoensis (Böse). *22, 24*, Upper surface and profile view of large form from Fredericksburg limestone, Loc. 10, 21 miles northwest of Alpine, Tex., ×0.75. *23*, Upper surface of a smaller form from Fredericksburg limestone, Loc. 3, University Mesa, near Fort Stockton, Tex., ×0.75. Both specimens from Smiser Coll., Princeton Univ. (p. 467)

25—Heteraster obliquatus (Clark). Upper surface of specimen from lower Fredericksburg limestone, Loc. 10, 21 miles northwest of Alpine, Tex., ×0.75. Smiser Coll., Princeton Univ. (p. 468)



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and usually somewhat rounded. In contour the test is oblong, nearly straight-sided with flattened posterior portion. Indentation by anterior ambulacrum slight. No fascioles. Ambulacra wide, very slightly flexed near the apex, and barely depressed; posterior paired ambulacra about two-thirds as long as anterior pair; anterior ambulacrum with pores en-chevron, pores of a pair separated by a granule in specimens not too badly weathered. Peristome pentagonal to subpentagonal. Periproct a narrow, elongate oval located high on flat posterior truncation.

Occurrence.—Trans-Pecos Texas: Upper Fredericksburg and lower Duck Creek at Loc. 10 (straight-sided, almost rectangular variety). North-central Texas: Fredericksburg and Duck Creek, Duck Creek type locality, Denison; widespread at this horizon in north-central Texas (less straight-sided more inflated variety with more rounded anterior and posterior).

Remarks.—As described here, this species is intended to include a somewhat variable group of forms very common in the Fredericksburg and Duck Creek at numerous widespread localities. All the forms are oblong; some are quite straight-sided, although this type is quite rare and, in so far as I am able to determine, peculiar to Trans-Pecos Texas. I have seen only two forms, both collected in west Texas, which show this character. They are *exactly* like Clark's figure 2*a*, pl. 43.

The most common type in north-central Texas is a little less straight-sided and slightly more inflated, with posterior truncation considerably more rounded. This latter type is more like Clark's actual type specimen than the straight-sided variety. His drawings seem to have been idealized, and they really resemble the straight-sided rare type much better than they do the specimen he intended to illustrate. This variety is much less common in Trans-Pecos than in north-central Texas.

PLIOTOXASTER INFLATUS Smiser, n. sp.
Plate 63, figures 1, 4, 15, 23–25

Test oblong, elevated, "swollen" or inflated in appearance; aboral surface high anteriorly in profile; posterior truncation sloping as in *Palhemiaster comanchei;* in contour test shows a slight angularity, flattened posteriorly by truncation. Carina very low, split. No fascioles. Peristome subpentagonal but tending to become labiate. Periproct a narrow, elongate oval high on posterior truncation.

Occurrence.—Trans-Pecos Texas: Kiamichi, Loc. 3. North-central Texas: Duck Creek in Munson Park, Denison. The specimen from this latter horizon and locality is slightly crushed, but it seems similar enough to be the same species.

Remarks.—This species gives every indication of being a passage form between *Pliotoxaster* and *Palhemiaster.* It agrees with the latter particularly in the character of the peristome. It differs from *Palhemiaster* in lacking a well-defined peripetalous fasciole, is much more elevated and inflated, and has more difference between the lengths of the anterior and posterior lateral ambulacra. In a comparison between some individuals of *Pliotoxaster inflatus* and *Palhemiaster comanchei,* I could find no difference except the distinct fasciole of the latter species. At one locality at least, University Mesa, Fort Stockton, the two species occur at very close horizons, the *Pliotoxaster* probably 10 feet lower in the Fredericksburg than the *Palhemiaster.*

The distinction between *Pliotoxaster* and certain genera of the family Brissidae is to a large extent in the more superficial ambulacra of *Pliotoxaster.* This distinction is, therefore, very delicate and sometimes requires very careful comparison and a somewhat arbitrary line of distinction. Usually the oblong character of the test is sufficiently apparent to aid in distinguishing *Pliotoxaster* from genera of Brissidae other than the fascioled types, and the lack of a fasciole will serve to distinguish it from the fascioled

Brissidae. I am placing within *Pliotoxaster* certain variable forms which actually may be closer to the Brissidae. The material at hand suggests that there are a number of forms in Texas with a somewhat oblong contour which are peculiar to this region and which are not really constricted posteriorly as in typical *Toxaster*. These forms, which have been included here under two species of *Pliotoxaster*, do not have the distinctly posterior apical system, conspicuous anterior ambulacral grooves and other characters of *Toxaster*. In these latter respects they more nearly resemble the Brissidae. Yet their ambulacra are more heterogeneous, less depressed, and their contour is usually more oblong than either *Macraster* or *Palhemiaster*. As previously mentioned, however, some specimens of *Pliotoxaster inflatus* do not differ from *Palhemiaster* even in this respect, but do differ in lacking a fasciole.

The necessary evolutionary changes to develop the Brissidae from *Toxaster*-like forms seem to be partly represented by this group. These changes include the progressive depression of the ambulacra and the anterior migration of the apical system, as the work of the anterior ambulacrum is partly distributed to the paired ambulacra. The advantage of such a change is very obvious.

Feeding in *Heteraster*, as representing typical Toxasteridae, was largely via the one groove, the anterior ambulacrum, which developed in size and depth proportionate to the duties expected of it. In the development of later forms the advantage of "radical" feeding was established and the paired ambulacra, with more nearly equal functions, all became depressed rather than superficial. The anterior one, being nearer the mouth, always remains most important as a food channel and is deeper or wider, at least different from the others, in varying degrees. Changes of this sort are most fundamental and are the best criteria for differentiating groups, even if the distinctions in the fossils *are* delicate. These changes are expressed as a result of different feeding habits, and hence are reactions to environment and change which produce new forms. The fully developed new form is seldom hard to

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EXPLANATION OF PLATE 65

All figures ×0.75.

FIGS. *1–4—Heteraster inflatus* (Cragin). Upper surface, profile view, lower surface, and posterior view of specimen from Del Rio clay, Loc. 17, 50 miles south of Alpine, Tex. West Texas Nat. Hist. Mus., Alpine. (p. 467)

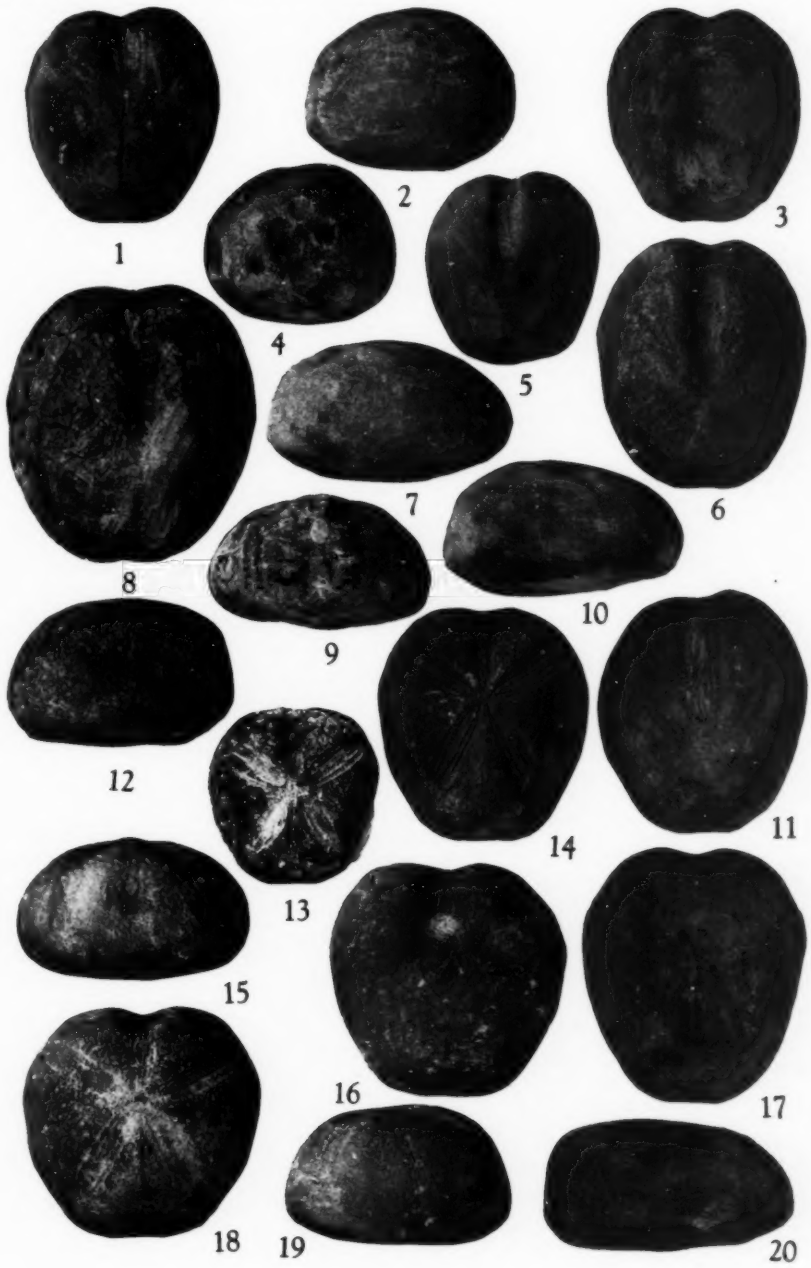
5–7—Heteraster wenoensis (Adkins). *5*, Upper surface of specimen from Washita beds (Fort Worth limestone or higher), Loc. 10, 21 miles northwest of Alpine, Tex. Smiser Coll., Princeton Univ. *6, 7*, Upper surface, and profile view of a larger specimen, from upper Georgetown limestone, Loc. 18, 50 miles south of Alpine, Tex. West Texas Nat. Hist. Mus., Alpine. (p. 469)

8—Heteraster cf. *traski* (Whitney). Upper surface of specimen from Buda limestone, Loc. 17, 50 miles south of Alpine, Tex. West Texas Nat. Hist. Mus., Alpine. (p. 469)

9, 12, 14, 17, 20—Pliotoxaster whitei (Clark). *9, 17, 20*, Posterior view, upper surface, and profile view of specimen from Duck Creek limestone, Loc. 10, 21 miles northwest of Alpine, Tex. Smiser Coll., Princeton Univ. *12, 14*, Profile view and upper surface of specimen of the more common inflated type that occurs in west and north-central Texas, from Duck Creek limestone at Odom Ranch, 5 miles south of Fort Stockton, Tex. Bur. Econ. Geology, Austin. (p. 464)

10, 11—Heteraster texanus (Roemer). Profile view and upper surface of specimen from Fredericksburg limestone, Loc. 10, 21 miles northwest of Alpine, Tex. Smiser Coll., Princeton Univ. (p. 468)

13, 15, 16, 18, 19—Macraster solitariensis Smiser, n. sp. *13*, Upper surface of a small paratype from the Glen Rose limestone, Solitario, Brewster-Presidio counties, *15, 16, 18, 19*, Posterior view, lower surface, upper surface, and profile view of holotype, from same horizon and locality. Figured specimens from collection Bur. Econ. Geology, Austin. (p. 472)



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recognize; but the transition form is difficult, because it actually seems to contradict itself at times when one tries to identify it specifically.

All forms of *Pliotoxaster* and of *Palhemiaster* invariably have the "granule" between pores of a pair in the anterior ambulacrum very conspicuously developed, much more so than in *Macraster*.

Genus HETERASTER d'Orbigny

HETERASTER BRAVOENSIS (Böse)

Plate 64, figures 22–24

Enallaster bravoensis BÖSE, *1910*, Inst. geol. México, Bol. 25, p. 168, pl. 41, figs. 5–10; pl. 42, figs. 2–12; pl. 43, figs. 1, 2, 6, 7.

Contour of test variable but average form shows a quite perceptible posterior constriction; broadest at middle, showing a constriction toward anterior end which is much less gradual than the posterior constriction; test inflated, less than in *H. inflatus* but more so than in other species of the genus; anterior slope gentle but persistent in profile, highest point on upper surface being formed by the posterior interambulacrum. Area of plastron prominent. Paired ambulacra narrow, the postero-lateral pair much longer than the antero-lateral; anterior ambulacrum in a rather deep groove with steep sides; pore-pairs have the 2:1 type of alternation. Apical system subcentral, slightly posterior. Peristome rounded or slightly transverse, posterior lip extended and slightly protruding. The periproct intermediate, being rounded on the upper portion and dropped to a slight point along the lower outline. Some individuals show a slightly transverse form, others a vertical elongate character for the periproct, but the average is as described.

Occurrence.—Common in the Fredericksburg. Large and small forms (as figured) are common in the Fredericksburg (Kiamichi) at Loc. 3, and at the same level at Loc. 10.

Remarks.—The larger forms have the deep, steep-sided ambulacral groove accentuated, and the anterior slope of the profile is steeper and more like *H. texanus* than in the smaller specimens. One specimen from the Glen Rose, Solitario Rim, between Presidio and Brewster City, Texas, was collected by W. S. Adkins.

A comparison of this species with *H. inflatus*, described and figured in this paper, suggests that this latter Washita species is closely related to or probably derived from *H. bravoensis*, which in turn was derived from *H. texanus*. The 2:1 alternation in the anterior ambulacrum is common to both. No significant difference is shown by the periproct and the profile of the test is so very similar that simple inflation of the earlier Washita species would account for the slight difference. The contour of the test is generally more rounded in *H. inflatus* and the profile more elevated. These distinctions, however, are best shown in the larger adult form figured in Plate 64, figs. 22 and 24. The smaller, and probably younger, form of this same species has a contour very similar to *H. bravoensis* (small).

HETERASTER INFLATUS (Cragin)

Plate 65, figures 1–4

Enallaster inflatus CRAGIN, *1893*, Geol. Survey Texas, 4th Ann. Rept., p. 150, pl. 24, fig. 13.

Contour of test oval, only slightly constricted posteriorly, very inflated in some individuals and so tall as to appear slightly globose; lower surface only slightly less convex than upper surface; anterior-posterior profile high, the anterior portion rounded and more declivitous, whereas the posterior curve is broken by the flat posterior truncation. Postero-lateral ambulacra short, the antero-lateral pair long; anterior ambulacrum in a deep wide groove, and porepairs have the 2:1 type of alternation. Apical system nearly central. Peristome nearly circular, posterior lip extended and projecting so that the opening is plainly seen from an anterior view of the test. Periproct nearly round, tending toward a broad vertical oval.

Occurrence.—Del Rio clay at Loc. 17

HETERASTER TEXASUS (d'Orbigny)
Plate 64, figures 15–18

Enallaster texasus D'ORBIGNY, *1853*, Paleontologie française, Terrain crétacé, tome 6, p. 184, pl. 850, figs. 1–7.

This species is identical with *H. bravoensis* (Böse) except that the pores of the anterior ambulacrum are in 1:1 alternation and the test seems a trifle more constricted posteriorly.

Occurrence.—Kiamichi at Loc. 10.

HETERASTER ADKINSI Lambert
Plate 63, figures 16–19

Enallaster texanus CLARK, *1915*, (not Roemer, 1858), U. S. Geol. Survey, Mon. 54, p. 86, pl. 39, figs. 2*a–g*.

Test less constricted than *H. bravoensis* (Böse) and more constricted than *H. mexicanus* (Cotteau), the highest point at the apical system or barely anterior to that point, whereas in *H. bravoensis* the highest point is far posterior. Test higher and more inflated than *H. mexicanus*. Anterior ambulacrum moderately deep, not broad, and the pore-pairs have the 1:1 type of alternation. Apical system barely posterior to center of test. Peristome rounded, posterior lip less projecting than in *H. inflatus* or *H. bravoensis*. Periproct a short, transverse oval with the lower border dropped to a blunt point in some specimens. This latter feature gives another similarity to *H. bravoensis*.

Occurrence.—Kamichi at Loc. 3, Kiamichi-Duck Creek at Loc. 10, Kiamichi at Loc. 8.

HETERASTER MEXICANUS (Cotteau)
Plate 64, figures 19–21

Enallaster mexicanus COTTEAU, *1890*, Soc. géol. France, Bull., (3), tome 18, p. 296, pl. 2, figs. 1–8.

Test broadly oval, not so elevated as *H. bravoensis* (Böse) or *H. adkinsi* Lambert. The species is close to *H. texanus* Roemer except that the apical system is distinctly posterior rather than subcentral. Anterior slope of test much more declivitous than any species except *H. obliquatus* (Clark). The low test, posterior apical system and short transverse periproct are all features common to *H. texanus* (Hall) (not Roemer) and *H. mexicanus* (Cotteau). These facts, together with the original figures and descriptions of the two species, indicate that *H. texanus* (Hall) and *H. mexicanus* are the same species. The anterior ambulacrum is moderately deep, broad, and the pore-pairs have the 1:1 type of alternation. Apical system posterior. Peristome transverse. Periproct a short transverse oval, in some species subcircular.

Occurrence.—Fredericksburg (Goodland and Kiamichi) at Loc. 3, same level at Loc. 10.

HETERASTER OBLIQUATUS (Clark)
Plate 64, figure 25

Enallaster obliquatus (CLARK), *1915*, U. S. Geol. Survey, Mon. 54, p. 87, pl. 40, figs. 1*a–l*.

Test very large, broad, and oval with declivitous anterior profile, not very elevated in view of its general size. Posterior paired ambulacra very short and curved, anterior pair, long and curved; anterior ambulacrum very broad, deep and more conspicuous than in any other species; pore-pairs of the anterior ambulacrum have the 1:1 type of alternation. Apical system posterior; peristome transverse; periproct a large transverse oval.

This species is similar to *H. texanus* (Roemer), differing mainly in size and position of the apical system. A distinct relationship is suggested, but the evidence at hand is not sufficient to draw any definite conclusions on just what the relationship is.

Occurrence.—Lower Fredericksburg at Loc. 10.

HETERASTER TEXANUS (Roemer)
Plate 65, figures 10, 11

Toxaster texanus ROEMER, *1853*, Die Kriedebildungen von Texas und ihre organischen Einschlüsse, p. 85, pl. 10, figs. 3*a–c*.

Test not greatly constricted posteriorly, widest considerably anterior to the apical system; upper surface generally

somewhat flat, the apical system and posterior interambulacral surface being at about the same level. In some specimens there is a slight arch in the upper surface profile, with highest point barely posterior to apical system. Upper anterior surface profile a gentle to moderately declivitous slope, a very gentle declivity being the average for the species. Posterior paired ambulacra about one-third as long as anterior pair; pore zones wide; anterior ambulacrum moderately wide and deep, with sloping sides much less steep than in most specimens of *H. bravoensis* Böse; line of pore-pairs for each side widely separated, each line located on the side slopes of the anterior groove; pore-pairs show the simple 1:1 type of alternation. Apical system posterior to center, but varying somewhat for individuals within the species. Some individuals show a somewhat subcentral position, which seems to be the normal, while others are quite similar to *H. obliquatus* (Clark) in having the apical system in a nearly posterior position. Peristome transversely oval to subrounded. Periproct an oval, typically elongated transversely.

Occurrence.—Common in the Kiamichi at Loc. 3, Fredericksburg (Goodland and Kiamichi) at Loc. 10, Kiamichi and Duck Creek at Loc. 5.

HETERASTER WENOENSIS (Adkins)
Plate 65, figures 5–7

Enallaster wenoensis ADKINS, *1920*, Univ. Texas, Bull. 1856, p. 112, pl. 5, fig. 3.

Test broad in outline, not constricted posteriorly; contour flattened posteriorly by truncation, anterior end more evenly rounded; test rather low and flat-topped with gentle anterior slope. Paired ambulacra prominent, the postero-lateral pair much shorter than the antero-lateral; unpaired ambulacrum in a wide, moderately deep, groove which decreases in width toward the anterior margin, so that indentation at the ambitus is narrower than the mid-portion of the groove; pore-pairs in anterior ambulacrum alternate irregularly. In one individual the right line of pore-pairs shows the 3:1 alternation from the apical system nearly to the ambitus, where the regular 1:1 alternation begins. The left line of pore-pairs has the regular 1:1 alternation except in one sequence where the alternation becomes the 2:1 type. Another specimen shows 2:1 alternation in the left line, 1:1 alternation in the right line. The anterior portion of one individual shows a faint peripetalous pseudofasciole. Apical system central. Peristome poorly defined in all the specimens collected, but seems to be subrounded, posterior lip prominent and anterior lip depressed; transverse dimension of opening greater than the longitudinal. Periproct a short transverse oval, the lower margin dropped to a blunt point.

Occurrence.—Washita at Loc. 10, just above the Duck Creek *Hamites* zone.

HETERASTER cf. TRASKI (Whitney)
Plate 65, figure 8

Enallaster traski WHITNEY, *1916*, Bull. Am. Paleontology, vol. 26, p. 15, pl. 8, figs. 1–3.

One specimen which probably represents this species is from the Buda at Loc. 17. All details of the test are removed but the general shape, character of profile, and contour are similar to this species.

Occurrence.—Buda limestone, Loc. 17.

Family BRISSIDAE Cotteau

The echinoids of this family are characterized by depressed ambulacra, and have been subdivided into three subfamilies by Lambert on the basis of (1) character of the peristome, (2) degree of depression and degree of flexure of the ambulacra, and (3) character of the fascioles when developed. Individually these characters are extremely delicate to use, but the combinations serve very well in subdividing the Texas Comanchean echinoids. The last-named character is difficult, often impossible, to determine, since the traces of the fascioles so frequently disappear on individuals which have been exposed long to

weathering. The fasciole is a good character by which to distinguish certain Tertiary echinoids, because it is largely a fixed character. But the Cretaceous forms represent an early development of fascioles, and they cannot be said to be fixed and may vary. However, in a few cases the fascioles are sufficiently well defined and persistent enough to be characteristic.

Sub-family PALEOSTOMIDAE Lambert

This sub-family includes genera which undoubtedly are forms of passage between the primitive Toxasteridae (represented by *Pliotoxaster* in Texas) and the Brissidae (groups within the sub-families Plesiasteridae and Periasteridae). These forms are characterized by either distinctly pentagonal peristomes or a type of peristome intermediate between pentagonal and labiate transversely oval. This intermediate type is best described as a transverse pentagonal or transverse subpentagonal. In this type of peristome the pentagonal character is quite apparent, but the labrum is high and extends forward slightly, anticipating the later labiate sub-families. The anterior margin of the peristome is depressed and it is wide transversely, anticipating the transversely oval type of the Plesiasteridae and Periasteridae. The ambulacra are characteristically straight, or only slightly flexed. They vary with the genera as to degree of depression, contrast in length between antero-lateral and postero-lateral pairs, and character of unpaired ambulacrum. Fascioles variable but, if present, they are always of the peripetalous type.

Genus MACRASTER Roemer

Test medium to large. Ambulacra long, variable in width, straight or only slightly flexed, and depressed, with little difference in length between the antero-lateral and postero-lateral pairs; pores in unpaired ambulacrum vary in arrangement but always at least suggest an arrangement *en chevron*. The smaller species have pores distinctly *en chrevron*, *in some cases separated by a granule*, whereas most of the larger species barely suggest an arrangement *en chevron*. This departure from distinctly *en chevron* to almost linear arrangement of the pores in the unpaired ambulacrum brings some of the Texas *Macraster* almost within the range of Lambert's genus *Douvillaster*, typically developed in Algeria. The Texas species of *Macraster* which do have almost linear pores in the unpaired ambulacrum are very much like *Douvillaster* in general size, contour, and other features.

The peristome is generally the transverse pentagonal type as described above, but some variation exists in which certain species, apparently more primitive and nearer *Pliotoxaster*, have distinctly pentagonal periprocts, while others, more advanced toward the sub-families Plesiasteridae and Periasteridae, show an almost labiate transversely subpentagonal periproct.

As an aid in classifying the different species of the genus, they may be some-

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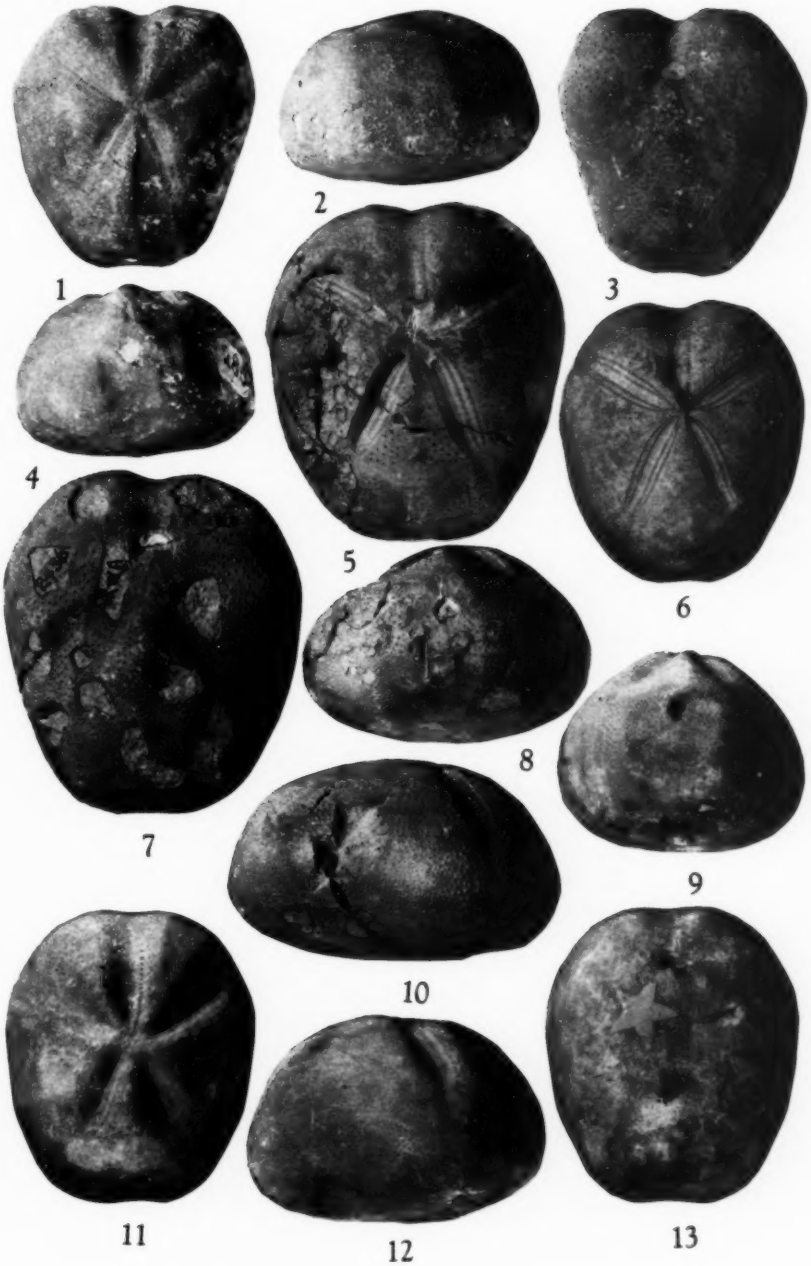
EXPLANATION OF PLATE 66

All figures ×0.75.

FIGS. *1–4—Macraster denisonensis* Smiser, n. sp. Upper surface, profile view, lower surface, and posterior view of holotype, from Duck Creek limestone at type locality, 3 miles north of Denison, Tex. Bur. Econ. Geology, Austin. (p. 471)

5–8, 10—Palhemiaster comanchei (Clark). *5, 7, 8, 10*, Upper surface, lower surface, posterior view and profile view of specimen from Walnut clay, 3 miles east of Tennessee Valley school, Bell County, Tex. *6*, Upper surface of another specimen from the same horizon and locality. Figured specimens from collection Bur. Econ. Geology, Austin. (p. 475)

9, 11–13—Hemiaster calvini Clark. Posterior view, upper surface, profile view, and lower surface of specimen from Grayson beds at Argyle, Tex. Bur. Econ. Geology, Austin. (p. 478)



Smiser, Cretaceous Echinoids

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what arbitrarily divided into two general groups on the basis of size in *adult* specimens. One group of species is composed of small to medium-sized forms and includes *M. solitariensis* Smiser, n. sp., *M. roberti* var. *ovatus* Smiser, n. var., *M. washitae* Lambert, *M. denisonensis* Smiser, n. sp., *M. nodopyga* Lambert, and *M. aguilerae* (Böse). The other group of species includes large forms, such as *M. texanus* Roemer, *M. pseudoelegans* Adkins, *M. obesus* Adkins, and *M. subobesus* (Adkins). The size of some individuals of *M. aguilerae* (Böse) closely approach the smaller individuals of the larger species. I have combined some previously described species where the differences are so small and of such a nature that they seem best interpreted as individual variation.

MACRASTER WASHITAE Lambert
Plate 67, figures 3, 5, 6, 9, 10

Hemiaster whitei CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 89, pl. 45, figs. 1*a–c*.

Test medium to large, of intermediate elevation, lower surface flattened, upper surface very slightly elevated almost evenly convex. Split posterior carina sufficiently developed in some individuals to interrupt the evenly convex profile of the aboral surface. Test very broad in contour, angular in outline with narrow posterior truncation; indentation by anterior ambulacral groove fairly deep; posterior truncation nearly vertical. Ambulacral areas prominent and rounded, the ambulacra rather deep, giving a rather hummocky appearance to the whole upper surface but not enough to cause confusion of this form with the sharp-appearing upper surface of *Hemiaster;* ambulacra wide, nearly straight, the paired ones being only slightly different in length; anterior ambulacrum with pores *en chevron*, sometimes separated by a granule. Peristome subpentagonal, depressed. Periproct broad oval, higher on posterior truncation than in other species of the genus. Traces of a peripetalous fasciole on some specimens, but not persistent or definite.

Occurrence.—Trans-Pecos Texas: Middle and upper Fredericksburg and lower Duck Creek at Loc. 8, and same horizon at Loc. 10. Widespread at this horizon in other areas in Texas.

Remarks.—The individuals of this species show a little variation, which has caused some doubt as to their generic assignment. The pores of the anterior ambulacrum form in some individuals a less distinct chevron arrangement, in which case the granule is usually not present. The combination of wide, depressed ambulacra of nearly equal length, broad polygonal contour, and pentagonal peristome marks these forms as belonging to *Macraster*. The pentagonal peristome rules out *Epiaster;* the depressed ambulacra and anteriorly broad contour rule out *Pliotoxaster*.

MACRASTER DENISONENSIS Smiser, n. sp.
Plate 66, figures 1–4

Test elevated, angular anteriorly, gradually constricted posteriorly to a moderately narrow, decidedly concave posterior truncation; contour similar to *M. washitae* but less polygonal, more nearly straight-sided and *Pliotoxaster*-like with a square-shouldered anterior; ambital margin or contour flattened on each side of the indentation of the unpaired ambulacrum; profile elevated above, very slightly inflated below over the plastron; the fairly evenly convex upper surface profile broken by a moderately developed carina, more conspicuous than in *M. washitae;* posterior truncation sloping anteriorly very little, and distinctly concave. Interambulacra moderately elevated on the upper surface, just a little more prominent than in *M. washitae;* ambulacra wide and deep, pairs nearly equal in length; anterior ambulacrum narrower, pores slit *en chevron*, separated by a distinct "granule." Peristome subpentagonal, depressed anteriorly, with elevated, nonprojecting labrum. Periproct a broad oval, barely above the mid-line of posterior truncation. No fascioles.

Occurrence.—Duck Creek, type locality, 3 miles north of Denison.

Remarks.—The square-shouldered form of this species might, on casual examination, cause some doubt as to whether it represents a form between *M. washitae* and some *Hemiaster* such as *calvini*, or between *M. washitae* and some *Pliotoxaster*. Undoubtedly the character of the upper surface, with prominent interambulacra and ambulacra deeper than common in *Macraster*, shows similarities to *Hemiaster*. However, the peristome is subpentagonal, *almost* pentagonal, which very important character places the species nearer to *Pliotoxaster*.

The one specimen in my possession is from the collections of the Bureau of Economic Geology, Austin, Texas, and with *Pliotoxaster whitei* (inflated variety common in north-central Texas) and *Macraster aguilerae*, was sent to me from the Duck Creek type locality.

MACRASTER SOLITARIENSIS Smiser, n. sp.
Plate 65, figures 13, 15, 16, 18, 19

Test small to medium in size and conspicuously wide. In a typical adult specimen the greatest width exceeds the length, but in most cases the width and length are approximately the same. Measurements of a small adult are: length 30 mm., width 30 mm., and height 18 mm. The holotype, a large medium-sized adult, measurements are: length 39 mm., width 41 mm., and height 24 mm. The broad contour is very slightly polygonal, truncated posteriorly but not flattened, indented moderately on the anterior by the unpaired ambulacrum. Upper surface profile fairly even convex, elevated somewhat toward the posterior; some individuals have a moderate carina, as shown by the holotype, but this character is variable. Lower surface profile inflated a small amount over the posterior end of the plastron, depressed toward the peristome and anterior. Posterior truncation sloping apically. Interambulacra elevated but not prominent; ambulacra depressed; anterior ambulacrum with slit pores *en chevron*, almost linear, in adults, separated by a "granule" less prominent as the linear character develops. Peristome subpentagonal or rounded pentagonal; poorly shown on all specimens at hand, but clearly enough to exclude any possibility of a transverse, labiate character. Periproct a broad vertical oval, high on posterior truncation. No visible fascioles.

Occurrence.—Glen Rose formation, Solitario rim, Brewster and Presidio counties, Texas.

Remarks.—This new *Macraster* differs sharply in general appearance from any other Texas echinoid which I have ever seen, excepting a few unusually wide specimens of *M. aguilerae*, from which it is easily distinguished by its more polygonal outline, more depressed ambulacra, and more elevated interambulacra. It resembles in some respects *M. silvaticus* Lambert, from the Aptien of Constantine. In this connection it is interesting to note that several small specimens associated with *M. solitariensis*, considered by me as young individuals of that species, more nearly resemble *M. silvaticus* than do the adults. In fact, the adult is wider, with much less posterior constriction. Further, I have collected from the Duck Creek at Loc. 10, one specimen so nearly like *M. roberti* Lambert that it is described below as a variety of that species. *M. roberti* occurs in the Vraconian of Andalousia. The Texan forms *M. solitariensis* and *M. roberti* var. *ovatus* Smiser, through their similarities and stratigraphic occurrence, suggest a connection, possibly the latter derived from the former, with the added suggestion that *M. aguilerae* followed as the latest representative of that same line.

MACRASTER ROBERTI Lambert and Thiéry, var. OVATUS Smiser, n. var.
Plate 64, figures 11–14

Macraster roberti LAMBERT AND THIÉRY, *1924*, Essai de nomenclature raisonnée des échinides, fasc. 6, 7, p. 472, pl. 12, fig. 1.

Test small, in the type of the variety 29 mm. long, 30 mm. wide, and 18 mm.

high. Lambert and Thiéry's figure of *M. roberti* is 37 mm. wide and 37 mm. long, height not shown or stated. Since only one specimen of the variety has been collected, no statement can be made regarding possible variation in size. The contour is broad, rounded, the slight posterior constriction rounded, as in *M. aguilerae*. Profile same as *M. solitariensis*, except that the posterior truncation is vertical, intermediate between the apically sloping truncation of *M. solitariensis* and the reversed slope of the truncation in *M. aguilerae*. Interambulacra not elevated, ambulacra almost superficial; anterior ambulacrum with slit pores forming shallow chevrons. Peristome obscured, but probably subpentagonal. Periproct a very wide, rounded oval, high on the posterior face.

Occurrence.—Duck Creek limestone at Loc. 10.

MACRASTER TEXANUS Roemer
Plate 67, figure 1

Macraster texanus ROEMER, *1888*, Neues Jahrb., vol. 1, pp. 191–195, pl. 6.

Test large, 75 to 80 mm. in length, 65 to 70 mm. in width, 35 to 40 mm. in height, somewhat oval in shape, narrowed but not decidedly constricted toward the posterior; elevation low; lower and upper surfaces usually flattened, but in some specimens the upper surface shows a gentle convexity in profile; posterior truncation a reversed slope. Ambulacra broad, straight, and depressed, antero-lateral pair reaching the ambitus and slightly longer than the posterior pair; posterior interambulacral area elevated above the other areas, forming the highest part of the test. Apical system depressed and located anterior to the center. Peristome transverse subpentagonal, near anterior margin. Periproct rounded or slightly oval vertically. Surface of the test marked by many small tubercles and granules which are not evenly distributed.

Occurrence.—Trans-Pecos Texas: This species occurs in a zone at the top of the Fort Worth associated with *M. subobesus* var. *kentensis* at Loc. 3. North-central Texas: Fort Worth limestone.

Remarks.—This species has certain characters which make it readily recognizable when compared with typical examples of apparently similar forms. Its low test with broader outline and less posterior constriction distinguishes it from *M. pseudoelegans*, to which it is probably most similar. The height is 50 per cent of the length or less. Although not rare, this species is far less common than *M. pseudoelegans*.

MACRASTER PSEUDOELEGANS Adkins
Plate 67, figure 2

Macraster pseudoelegans ADKINS, *1930*, Univ. Texas, Bull. 3001, p. 108, pl. 10, figs. 1, 5; pl. 11, fig. 4.

The test varies considerably but is similar in many respects to *M. texanus* Roemer. It is less pointed than *M. subobesus* var. *kentensis* Adkins, but a little more acute than *M. texanus*. It can also be distinguished partly by its narrow ambulacra. The contour of the test is not polygonal, as in some individuals of *M. subobesus* var. *kentensis*, but more oval, as in *M. texanus*. Posterior interambulacrum only slightly elevated. The great similarity to *M. texanus*, combined with its elevated test, which is more than 50 per cent of the length, is the best character for distinguishing this very common species. Apical system anterior to center. Peristome transversely subpentagonal. Periproct vertically oval and medium in size, located about the center of posterior truncation.

Occurrence.—Trans-Pecos Texas: Very common in a zone at the top of the Fort Worth formation at east end of 7-Mile Mesa where search that was not exhaustive yielded no other species. Examples of this species were found in the *Macraster* zone of the Fort Worth at University Mesa where the zone is marked by *M. subobesus* var. *kentensis*. Very common in the Fort Worth and Denton of central and east-central Texas. Undoubtedly the most common of the group of larger species and very wide-

spread. Great variation in size, but proportions and general appearance always the same.

MACRASTER SUBOBESUS (Adkins)

Epiaster subobesus ADKINS, *1920*, Univ. Texas, Bull. 1856, p. 110, pl. 11, fig. 3.

Test large, length 80 to 85 mm., greatest width anterior to center about same as length, 78 to 83 mm., height 40 to 45 mm.; very wide in anterior portion and gradually narrowing to a somewhat pointed posterior face. Lower surface flattened, upper surface distinctly elevated with mid-line of posterior interambulacrum rather sharp. Ambulacra long, wide, and little depressed. Apical system anterior to the center and depressed. In the specimen described and figured by Adkins the madreporite is large and elevated, standing out conspicuously from the apical system. One specimen collected by me from the Fort Worth limestone at University Mesa also shows this feature. Peristome transverse subpentagonal, depressed. Periproct circular or only slightly oval vertically, located low on posterior truncation.

Occurrence.—Trans-Pecos Texas: Fort Worth formation at Loc. 3. In float on Duck Creek outcrop at Loc. 6, the specimens collected here having doubtless weathered from the Fort Worth or higher Washita beds, but it is possible that they might have come from a former remnant of the Fort Worth that may have overlain the Duck Creek at this point.

Remarks.—This species is chiefly distinguished by its extreme posterior constriction and smooth outline.

MACRASTER SUBOBESUS (Adkins)
var. KENTENSIS Adkins
Plate 67, figure 4

Macraster kentensis ADKINS, *1930*, Univ. Texas, Bull. 3001, p. 106, pl. 11, figs. 1–3, 5.

This variety differs from *M. subobesus* only in its smaller size and slightly polygonal contour.

Occurrence.—Trans-PecosTexas: Duck Creek and Fort Worth formations at Fort Stockton, best material from Loc. 3. Adkins states the variety occurs in central Texas, although I have never seen a single specimen from any area other than west Texas, and the variety seems to be characteristic of that region.

MACRASTER AGUILERAE (Böse)
Plate 67, figure 7

Epiaster aguilerae BÖSE, *1910*, Inst. geol. México, Bol. 25, p. 173, pl. 37, figs. 2–4, 6, 7; pl. 38, figs. 1, 2, 4.
Epiaster wenoensis ADKINS, *1920*, Univ. Texas, Bull. 1856, p. 105, pl. 6, fig. 6.

Test medium to large, in contour a short very broad oval and very low;

EXPLANATION OF PLATE 67

All figures ×0.75.

FIGS. *1*—*Macraster texanus* Roemer. Upper surface of specimen from Fort Worth limestone. Loc. 3, University Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 473)

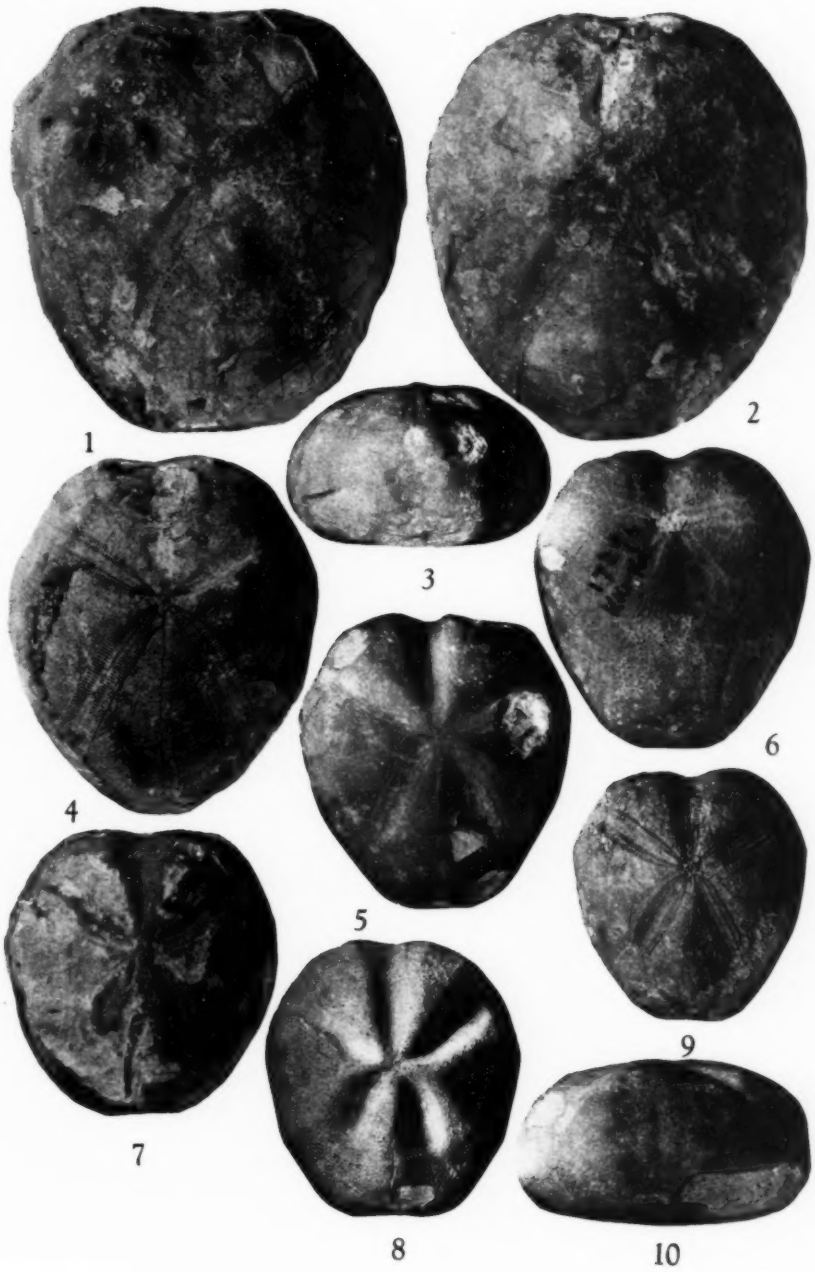
2—*Macraster pseudoelegans* Adkins. Upper surface of specimen from Fort Worth limestone, Loc. 3, University Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 473)

3, 5, 6, 9, 10—*Macraster washitae* Lambert. *3, 5, 6, 10*, Posterior view, upper surface, lower surface, and profile view of specimen from Kiamichi-Duck Creek beds, near Fink, Grayson County, Tex. Bur. Econ. Geology, Austin. *9*, Upper surface of a specimen from Duck Creek limestone, Loc. 8, Triple Hill, southwest of Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 471)

4—*Macraster subobesus* var. *kentensis* Adkins. Upper surface of specimen from Duck Creek limestone, east end of 7-mile Mesa, near Fort Stockton, Tex. Smiser Coll., Princeton Univ. (p. 474)

7—*Macraster aguilerae* (Böse). Upper surface of specimen from Duck Creek limestone at type locality, 3 miles north of Denison, Tex. Bur. Econ. Geology, Austin. (p. 474)

8—*Hemiaster calvini* Clark. Upper surface of specimen from Grayson beds, Bell County, Tex. Bur. Econ. Geology, Austin. (p. 478)



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upper surface only slightly elevated; lower surface flattened; width just anterior to center nearly equal to length. Ambulacra narrow, very shallow, almost superficial, and straight; interambulacral areas not elevated, except the posterior area which forms the highest portion of the test. Apical system nearly central. Peristome obscured on specimens collected, but should be transverse subpentagonal and near anterior margin. Periproct vertically oval to nearly circular in some individuals. Surface of the test quite smooth, with very few tubercles or granules.

Occurrence.—Trans-Pecos Texas: In float on Duck Creek outcrop at east point of 5-Mile Mesa, Fort Stockton, associated with *M. subobesus* (also in float). Doubtless came from former overlying remnant of the Fort Worth or carried here from farther back on the mesa where the Fort Worth is present. At west end of 12-Mile Mesa just below the Fort Worth limestone. Specimens not in place, but at this place they must have come from Fort Worth beds immediately above the position where found. In north-central Texas from the Duck Creek type locality, 3 miles north of Denison.

Remarks.—Adkins has previously suggested that his *M. wenoensis* might be the same as *M. aguilerae*. I believe them to be identical and have so treated them.

Genus PALHEMIASTER Lambert

PALHEMIASTER COMANCHEI (Clark)

Plate 66, figures 5–8, 10

Hemiaster comanchei CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 90, pl. 46, figs. 2*a–d*.

Test medium to large, elevated but not inflated, evenly convex above, flattened below, except over plastron where it appears swollen; posterior truncation slanting, almost blending into the evenly convex profile of upper surface; contour of test oblong, sides almost straight, sometimes showing a very slight angularity, posterior constriction of the contour not marked. Ambulacra only moderately depressed and of nearly equal length; unpaired ambulacrum barely indents the anterior contour of the test; pores of interior ambulacrum *en chevron*, with a granule between the pores of a pair. Periproct a transverse pentagonal with some tendency toward a labiate character, as shown by elevation of the labial plate behind and depressed anterior portion. A distinct peripetalous fasciole distinguishes this form from *Pliotoxaster*, and from other genera of the sub-family Palaeostomidae. Distinguished from the Periasteridae by its pentagonal peristome.

Occurrence.—Trans-Pecos Texas: Fredericksburg just a few feet below the Duck Creek limestone at Loc. 3. Apparently most common in the Walnut of central Texas, Bell County, at a locality 3 miles northwest of Tennessee Valley School.

Genus LAMBERTIASTER Gauthier

LAMBERTIASTER FICHEURI Dalloni and Lambert

Plate 64, figures 1–3, 9, 10

Lambertiaster ficheuri LAMBERT AND THIÉRY, *1924*, Essai de nomenclature raisonnée des échinides, fasc. 6, 7, p. 474, pl. 12, figs. 3–5.

Test medium in size, 33 mm. long, 30 mm. wide, 21 mm. high, conspicuously tubercled; contour oblong as in *Pliotoxaster*, from which it can be distinguished by the more depressed ambulacral grooves; contour at sides shows a slight angularity, the posterior flattened by the narrow truncation of the constricted posterior face; ambitus indented very little by unpaired ambulacral groove; profile of upper surface even, except where elevated by a moderately developed keel; posterior truncation sloping, but not enough to blend into profile, as in *Palhemiaster comanchei;* lower surface profile a little inflated over the plastron, depressed on anterior and lateral sides of peristome. Interambulacra moderately elevated, separated by the fairly wide depressed ambulacra; postero-lateral ambulacra about two-fifths the length of the antero-lateral;

unpaired ambulacrum narrower with short slit pores *en chevron* and separated by "granule"; inner pore small; plates of unpaired ambulacrum sharply bent, different from plates of paired ambulacra. Peristome sharply pentagonal, the labrum elevated. Plastron amphisterne. Periproct a slender vertical oval, rounded a little more at the top than at the bottom. No distinct fasciole, but some individuals show a slight tendency to develop a peripetalous fasciole around the sides and posterior.

Occurrence.—Trans-Pecos Texas: Duck Creek limestone at Loc. 10. Very rare in west Texas. Common in the Fredericksburg and Washita of north-central Texas.

Remarks.—This species, new to Texas, is rare in west Texas, common in north-central Texas, and is undoubtedly the one most commonly miscalled "*Epiaster whitei.*" Other forms described in this paper as *Pliotoxaster* have also been called "*Epiaster whitei,*" but not so frequently. *Lambertiaster ficheuri* is the species so often pointed out as "the typical *Epiaster whitei.*"

Lambert's measurements show his form to differ only in size and in elevation as a percentage of width, height, and length. These differences are so slight that they seem insufficient even to warrant the establishment of a new variety in my opinion.

Genus LEIOTOMASTER Lambert

LEIOTOMASTER BÖSEI Smiser, n. sp.

Plate 64, figures 4–8

Hemiaster sp., BÖSE, *1918*, Univ. Texas, Bull. 1856, p. 232, pl. 20, figs. 6–10.

Test small, 17 to 21 mm. wide, 18 to 22 mm. long, 14 to 17 mm. high, elevated, inflated below over the plastron, irregularly sharp on upper surface; sides high and evenly rounded at ambitus; contour short anteriorly-posteriorly, barely oblong, slightly polygonal along the sides at the posterior paired interambulacra; posterior portion of contour flattened by the posterior truncation; anterior indented moderately by the unpaired ambulacral groove; anterior contour at ambitus not quite symmetrical on the two sides of the indentation caused by the unpaired ambulacra; the right "lobe," formed at ambitus in the right antero-lateral interambulacrum, more prominent than that on the left of the indentation. This last character is shown distinctly on two perfect specimens, and rather indistinctly on others. Böse's figure 9 shows the same feature, which probably resulted from adaptation of the test to accommodate some internal adjustment. It doubtless results from the fact that the genital plate which bears the madreporite is located at the apical termination of this interambulacral area. This peculiar asymmetry is not uncommon, and within the family Brissidae seems to be an individual, rather than a specific or generic character. It is very common, almost the rule, among species of the genus *Heteraster*, of the family Prospatangidae. Test elevated posteriorly in profile, depressed anteriorly but not declivitous; profile of upper surface very high along the sharply elevated posterior carina, dropping abruptly at the apical system, and rounding off anteriorly; lower surface profile inflated over the plastron, depressed at the peristome; the slightly concave, decided posterior truncation slopes a little toward the anterior.

Interambulacra sharply elevated, separated by deeply grooved ambulacra; unpaired ambulacral groove a little narrower than paired grooves, with almost rounded pores separated by a "granule." Lambert (1920, p. 20, pl. 1, figs. 15–19), in describing and figuring the genotype, *L. gentili*, says that the plates are convex, so as to give an embossed character to the test. Even the most perfect specimens I have seen are undoubtedly somewhat weathered, and this character does not seem so apparent as Lambert's figure of the genotype shows. But the surface of the test does show an irregularity probably resulting from convexity of the plates.

Apical system in a depressed position between the apical terminations of the elevated interambulacra, centrally located; it is perfectly preserved on most specimens because it is depressed. Peristome pentagonal to transverse subpentagonal in outline. A comparison of the two perfect specimens whose measurements have been given above, one small and one large, shows an interesting variation in the peristome, which is doubtless a result of the age of the individual. The smaller, apparently younger, specimen shows clearly a geometrically pentagonal peristome, apparently retaining in youth a character from some ancestral form within the family Prospatangidae. The larger, older specimen shows the transverse subpentagonal peristome more nearly characteristic of the passage forms which comprise the sub-family Paleostomidae. The labrum is elevated but does not project conspicuously. Periproct a narrow vertical oval, located very high on posterior face.

Occurrence.—Eagle Ford, 3 miles east of Langtry and 13 miles south of Del Rio. The specimens, 15 in number and including numerous fragments, were collected by Dr. W. L. Moreman.

Remarks.—This species is similar in many respects to *Hemiaster texanus* Roemer, and is possibly the ancestor of that species. Incompleteness of information and lack of figures for *Hemiaster americanus* Giebel make a comparison with that form impossible. The characters which the species shows are *Hemiaster* characters, except the peristome, which places it beyond a doubt within the sub-family Paleostomidae.

Sub-family PLESIASTERIDAE Lambert

Lambert has described one representative of this sub-family from the Texas Cretaceous as *Epiaster bösei*. His description and figures fit just as well some of the very numerous young of other genera withi the Brissidae. Apparently he was unable to determine the character of the peristome, since he states that it was poorly preserved. A great many young forms of *M. washitae*, and even of *Pliotoxaster whitei* (inflated variety) so closely resemble his description and figures that it seems possible he may have mistaken a young form for a different species. As an added point, the young of some of the sub-family Paleostomidae have the superficial ambulacra held over in youth from *Pliotoxaster* ancestors which he attributes to his *E. bösei*. Also, if his specimen did not show the peristome, the species seems further in doubt.

Sub-family PERIASTERIDAE Lambert

Includes the Brissidae with peripetalous fasciole, no sub-anal fascioles, sometimes marginal fascioles connected to the peripetalous fasciole, and with transverse labiate peristomes.

Genus HEMIASTER Desor

This genus contains the sole representatives of the Periasteridae so far discovered in the Texas Cretaceous. The genus is characterized by the transverse labiate peristome and a sole peripetalous fasciole which does not extend forward to the anterior paired ambulacra. Additional characters which distinguish forms of this genus in Texas are the sharply elevated interambulacra and conspicuous carina, extreme elevation of the test, deeply depressed ambulacra, the postero-lateral pair much more shorter than the antero-lateral. The genus is represented in Texas by *H. calvini* Clark, *H. texanus* Roemer, *H. bexari* Clark, and *H. americanus?* Giebel, the last species, described but not figured, being doubtful, for it may be the same as *H. texanus*. In the absence of figures and type material, *H. americanus* is not considered valid. Only *H. calvini* is described here as a typical representative of the group, and it is the only one collected from the area primarily considered in this paper.

HEMIASTER CALVINI Clark

Plate 66, figures 9, 11–13; Plate 67, figure 8

Hemiaster calvini BÖSE, *1910*, Inst. geol. México, Bol. 25, p. 175, pl. 43, figs. 3, 4, 5, 8; pl. 44, figs. 1–8.

Test medium to large, very elevated but not inflated; contour oblong, in some specimens slightly polygonal; anterior part barely indented by unpaired ambulacrum, posterior more or less flattened by truncation; profile of upper surface high and sharp, in some cases with very high carina as in *H. texanus* (the latter distinguished by its lower test and broader anterior ambulacrum and sloping posterior truncaton); lower surface profile inflated over the plastron; posterior truncation vertical. Interambulacra high and sharp with deeply depressed ambulacra between; anterior ambulacra with ovoid slit to round pores, pores of a pair separated by a "granule." Peristome transversely oval, labiate. Periproct vertical oval, high on posterior face. Peripetalous fasciole extending only to anterior paired ambulacra, distinct on well preserved specimens.

Occurrence.—Trans-Pecos Texas: Upper Del Rio formation at Loc. 17. Common in the Grayson of north-central Texas, Del Rio of south Texas.

Remarks.—Two very large and excellently preserved individuals of this species have been sent to me from the collections of the Bureau of Economic Geology, Austin, one from the Grayson of Bell County, another from Argyle, Texas. These particular specimens are the largest and best preserved representatives of this species which I have yet seen.

SUMMARY

Trans-Pecos Texas includes Lower Cretaceous rocks of both the northern and southern facies. Toward the north, in the area around Fort Stockton, the soft alternating limestones and shales of the northern facies yield an echinoid fauna very much like that of north-central Texas. This part of the Trans-Pecos region has not to date yielded as many species, but those which do occur are either identical with or very similar to species from the same facies in north-central Texas. Southward the northern rock facies thins, the soft alternating limestones and shale eventually giving way to massive limestones of the southern facies. Echinoids are rare in this massive Edwards and Georgetown limestone, but farther south in the Big Bend country, the Del Rio clay and Buda limestone (which in places cap the Georgetown-Edwards) contain practically the same echinoid fauna that they show to the east and south-central Texas.

Since the localities from which collecting was done represent a north-south series across the strike, some interesting features of the change can be seen. Near Fort Stockton the rocks and fauna are typical of the northern facies. The region represented by Loc. 9 and 10 (see fig. 1), approximately 45 miles southwest of Fort Stockton, still shows a facies of the northern type, but significant changes have occurred. The Fredericksburg here becomes thinner, although yielding much the same echinoid and other invertebrate fauna. The echinoid zones of the Fredericksburg still persist, but the *Holectypus* group, so abundant at University Mesa (Loc. 3), is comparatively rare, and *Salenia prestensis*, rare at University Mesa, is common at Loc. 10. *Heteraster* continues to dominate the echinoid fauna here as farther

north. The "Fredericksburg clay" is prominent here, forming a "yellow horizon" which can be recognized even at a distance.

The Washita has undergone other changes in addition to considerable thinning. The fossil zones are much closer together, and numerous species prominent in the Washita farther north are lacking. The Duck Creek *Hamites* persist, but the larger Duck Creek ammonities were not found. Numerous species of echinoids, such as the larger Fort Worth species of *Macraster*, are completely wanting.

Between the area represented by Loc. 9 and 10 and the Southern Pacific Railroad, about 10 miles farther south, the southern facies has begun to develop. Unfortunately the outcrops between these two points are not as extensive as might be wished, but those studied in this area show a very hard white limestone which carries a Fredericksburg fauna without echinoids. This limestone is not so massive as the Edwards to the south, but is harder and more massive than that characteristically encountered in the northern facies.

South of the Southern Pacific Railroad, Washita time is represented by the Georgetown beds in which separate formations are less distinct. The Georgetown becomes increasingly more massive as it is followed southward. The same is true for the Fredericksburg, and these together eventually form one thick, massive limestone in southern Brewster County. This massive limestone can probably best be seen about 15 miles south of Terlingua in the Grand Canyon of the St. Helena where the Rio Grande has cut a canyon approximately 1,700 feet into it. Here the limestone is on the upthrown or southwest side of a fault which strikes approximately southeast-northwest. On the northeast side of the fault are found the Terlingua beds (Upper Cretaceous). Echinoids are very rare in the Georgetown-Edwards beds.

An explanation of the change in the echinoid fauna from north to south can best be found through an interpretation of the physical conditions of deposition as indicated by the rocks. The northern facies of alternating sandstone, shale, and impure limestone represents a comparatively shallow water and probably near-shore environment in which echinoids would find ideal conditions for development. The more massive southern facies, being farther from shore and possibly, although not necessarily, deeper offered less favorable conditions for echinoids, due to lack of food supply, temperature, and bottom conditions. In accepting this explanation, it is necessary to consider the Del Rio and Buda, which overlie the limestones to the south, as representing a recurrence of near-shore conditions occasioned by a change in the position of the late Washita sea.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 6, PP. 481–489, PLS. 68–72, TEXT-FIGS. 1, 2,
SEPTEMBER, 1936

SOME MID-PENNSYLVANIAN INVERTEBRATES FROM KANSAS AND OKLAHOMA: III. CEPHALOPODA

NORMAN D. NEWELL

ABSTRACT

Seven kinds of cephalopods are described from the Kansas Pennsylvanian, one new ammonoid, *Pronorites kansasensis*, and six new nautiloids, *Coloceras milleri*, *Mooreoceras condrai*, *Kionoceras* sp., *Koninckioceras jewetti*, *K. eliasi*, and *K. wyandottense*. The genera *Koninckioceras* and *Kionoceras* have not heretofore been recorded in the American Pennsylvanian.

This is the last of a series of papers (Newell, 1934, 1935) devoted to the description of new species of invertebrates discovered in a recent stratigraphic and faunal survey of the upper part of the Missouri series in Kansas and northern Oklahoma. The present paper deals exclusively with cephalopods.

The material forming the basis of this paper is deposited in the geological museum of the University of Kansas, except for some paratypes which are in the Peabody Museum, Yale University.

It is fitting to express especial gratitude for the council of Drs. C. O. Dunbar and J. Brookes Knight. Mr. J. M. Jewett generously lent some of the specimens here described and assisted in the collecting of other cephalopod specimens.

SYSTEMATIC DESCRIPTIONS

Phylum CEPHALOPODA

Genus COLOCERAS Hyatt, 1893

COLOCERAS MILLERI Newell, n. sp.

Plate 68, figures 1*a*–4; Plate 69, figures 1, 2; Plate 70, figure 1

This is a subglobose nautilicone attaining a diameter at full maturity of about 9 cm. Adults have about three and one-half volutions, of which the living chamber occupies about the last one-fourth whorl. The whorls are deeply impressed so that each volution is almost, but not quite completely embraced by the succeeding one. The expansion is uniform in the outer whorls and rapid so that each whorl has approximately twice the height and width in section of the preceding one.

At the end of the first one-half volution the shell has a diameter of $3\frac{1}{2}$ mm. The whorl section at this stage is subcircular, a little higher than wide, with a suggestion of being a little narrower near the venter; the siphuncle is slightly dorsal to the center. At the end of the first volution the shell is 10 mm. in diameter. There is a faint suggestion of a flattening at the venter and dorsum, but otherwise the section is transversely elliptical, and the first appearance is made of a shallow impressed zone. The widest part of the whorl section is just below the mid-line of the sides. At this stage the siphuncle is still very slightly on the dorsal side of the center. At one and one-half volutions a diameter of 17 mm. is attained in the conch and the whorl is bean-shaped in section, with a semicircular venter, ill-defined umbilical shoulders and a nearly flat dorsum. The impressed zone is well defined, completely embracing the previous whorl; the siphuncle is central, as measured be-

tween the venter and the umbilical slopes, but it is slightly dorsad if the center of the impressed zone be used as a reference. At two volutions the conch attains a diameter of 27 mm. and at two and one-half, 45 mm. In these and later stages the venter and sides are semicircular in section and the umbilical slopes flare outward more conspicuously than in the earlier whorls.

At about the middle of the second volution an umbilical plug seals the umbilicus and its continuation in the later stages forms a solid axis or columella, so that the inner volutions are not visible in the umbilicus of a mature individual. The siphuncle in the later volutions is slightly dorsad to the center if the center of the impressed zone is used as a reference, but as compared to the umbilical slopes the siphuncle is slightly on the ventral side of the center.

Internal molds show a single faint raised line along the middle of the venter as do many fossil nautiloids. This line evidently reflects on obscure groove at the interior of the shell, such as can be seen in specimens of the modern *Nautilus pompilius*, but its significance is not clear.

The muscle marks are distinct in several specimens, appearing as two small lateral crests, each of which extends a third of the distance from the umbilicus to the mid-line of the venter. The scar is shown on either side of internal molds by a faint line emerging from the umbilicus at a point near the base of the living chamber and extending transverse to the volution for about 1 cm. before it swings aborally in a small symmetrical arc, thence extending backward as a straight line separating the lateral and ventral surfaces into three areas, a broad ventral area and two relatively narrow ventro-lateral areas. Inspection shows that these ventro-lateral areas, bounded on the molds by the lines alluded to above, are covered by a thin film of calcite which in well-preserved specimens covers the sutures. It is the abrupt margin of this calcite film that produces the lines bounding the muscle scars. Apparently the thin calcite layer is a resistant original part of the shell which adheres for some reason to the mold after the outer part of the shell is broken away. In *Nautilus pompilius* such a calcareous film of "scar tissue" is formed at the insertions of the muscles in the shell substance. It is the hypostracum layer. In the specimens of *Coloceras milleri*, n. sp., the anterior margin of the muscle scars extend only a few millimeters ahead of the sutures. The last septa in these specimens exhibit gerontic crowding and it is probable that the muscles actually were not attached so close to the septa. It might be supposed that the anterior border of the visible muscle scar indicates the position of the muscles at full maturity and as the muscles migrated forward during the following senescence they had a relatively insecure attachment to the shell, not recorded by a distinct scar.

Growth lines impressed upon one internal mold show a deep and relatively narrow hyponomic sinus having a backward flexure of about 15 mm. at a shell diameter of 7 cms. In one imperfect topoparatype there is a badly altered fragment of the shell in the umbilical region which exhibits coarse but very indistinct revolving costae, and the molds in a few specimens exhibit exceedingly obscure

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EXPLANATION OF PLATE 68

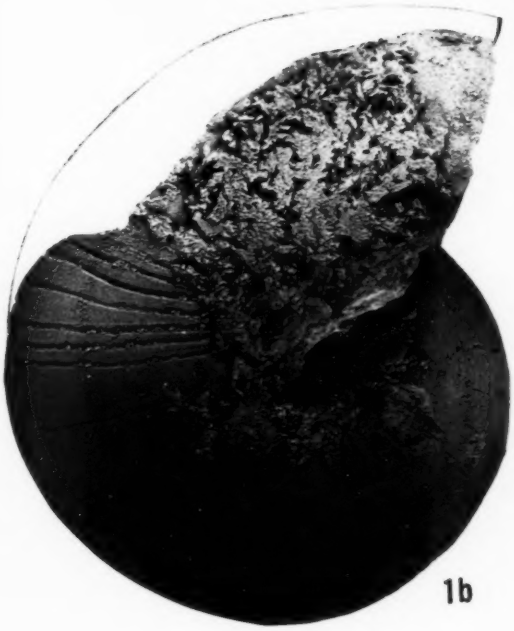
FIGS. *1–4*—*Coloceras milleri* Newell, n. sp. *1a, b*, Apertural and side views of the holotype, ×1, from the Farley limestone, just east of De Soto, Kansas. *2*, Polished dorso-ventral section, ×2, of a paratype found associated with the holotype. *3*, Ventral view of a paratype, ×1, from Kansas City, horizon unknown, showing a peculiar median saddle appearing in late maturity; a lateral view of this specimen is shown on Plate 70, fig. 1. *4*, Dorsal and septal view of a paratype found with the holotype, ×1.

(p. 481)

1a

2

3



1b

4

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traces of revolving ornamentation on the sides.

The sutures in the juveniles are straight and transverse, acquiring in more mature individuals a broad ventral saddle and an obscure dorsal lobe corresponding to the impressed zone. The flexures commonly first appear at a shell diameter of about 2½ cm. measured in the plane of coiling, but there is considerable variation in this respect, and one paratype having a transverse diameter of more than 4 cms. still retains straight sutures, whereas another specimen at the same size exhibits distinct ventral saddles. This kind of variation is shown in several specimens from the same locality and horizon. At a shell width of 4.5 cm. in the holotype, the septa are spaced 1 cm. apart along the mid-line of the venter. At a shell diameter of 3.2 cm. in a topoparatype, the spacing between successive septa is about 6 mm. Some specimens show gerontic crowding of septa at a shell diameter of 7 cm.; others do not exhibit this character before a maximum diameter of 8.5 cm. is reached. This difference is probably not specific because the two kinds of shells are found in association, but it may represent some biologic distinction like *sexual dimorphism*.

The siphuncle is 2 mm. or more in diameter at a mature stage and is one diameter or less dorsad to the center. In structure it is orthochoanitic with cylindrical connecting rings, except in the juvenile stages where there is a tendency toward very slight expansion within the camerae. At a dorso-ventral height of 2 cm. measured on a septum from the center of the impressed zone, the convexity of the septum is 5 mm.

In the collections at hand there are twenty internal molds of the new species of *Coloceras*, many of them nearly complete, but the shell is scarcely preserved in any of them.

The species is dedicated to Dr. Arthur K. Miller of the University of Iowa.

Discussion.—This species is not likely to be confused with any described species of *Coloceras* from the American Pennsylvanian. It may be distinguished easily by its closed umbilicus, deeply impressed whorls, and its relatively large size.

Distribution.—The holotype and several paratypes were collected in the oolitic Farley limestone along Kill Creek at De Soto, Kansas. It is also known from the Winterset limestone at Kansas City and doubtfully from the upper Argentine limestone near Welborn, Kansas.

Genus MOOREOCERAS Miller, Dunbar, and Condra, 1933

MOOREOCERAS CONDRAI Newell, n. sp.

Plate 69, figures 3*a–e*

The conch is a slender orthoceracone with an apical angle of about 8.5 degrees. The shell section is elliptical, being slightly broader than high in the ratio of about 1.07 to 1 in the holotype. The species is represented in our collections by several internal molds, none of which show the surface of the shell. The holotype is a well-preserved fragment of a phragmocone about 87 mm. long, including 23 camerae. Near the middle of the specimen it has a width of 24 mm., a height of 22.3 mm., and the diameter of the siphuncle is about 1.5 mm. Apparently the conch originally had a length of at least one foot. Above the mid-line of the lateral areas the sutures are straight and transverse, but on the ventro-lateral areas they bend forward slightly, passing into a broad ventral saddle. The sutures are rather closely spaced, 10 camerae occupying a space of 40 mm. when the width of the mold is from 23 mm. to 29 mm. The convexity of a septum 24 mm. wide is 3.9 mm.

The siphuncle is cyrtochoanitic and is a little nearer the venter than to the midpoint of the shell section. The connecting rings are inflated within the camerae as they are in the genotype of *Mooreoceras*. The septal necks extend backward about one-third of a millimeter at a shell width of 23 mm.

The species is dedicated to Dr. G. E. Condra of the Nebraska Geological Survey.

Discussion.—There are two other Pennsylvanian species of *Mooreoceras* which might be confused with the one just described. These are *Mooreoceras normale angusticameratum* Miller, Dunbar, and Condra and *M. bakeri* Miller, Dunbar, and Condra. The type of the former is known from the Kendrick shale of Pottsville age in Kentucky. The second one was described from the Burlingame limestone, of Virgil age, in Kansas. The types of these two forms have been compared directly with the new species and the following distinctions can be made. The septa in the Kentucky form are slightly more convex than in the new species, having at a shell width of 21 mm. a dorso-ventral convexity of 4.5 mm., whereas at an equal shell width in *Mooreoceras condrai*, the convexity of the septa is only 3 mm. *M. bakeri* is very similar to *M. condrai*, but it can be readily distinguished by its longer camerae. At a length of 87 mm. in *M. condrai* there are 23 camerae. At an equal length there are only 18 camerae in *M. bakeri*. In other respects the two species are much alike.

Distribution.—The new species is not uncommon in the Kansas City and Lansing groups. It has been found in the oolitic facies of the Farley limestone at De Soto, Kansas (holotype), in the Merriam limestone, near Paola, Kansas, and near the top of the Argentine limestone, northeast of Welborn, Kansas.

Genus KIONOCERAS Hyatt, 1883

KIONOCERAS sp.

Plate 70, figures 2*a–c*

This form is known from two small fragments of the phragmacone including the molds of a half dozen or so of the camerae. The diameter is only about 2.5 mm. The siphuncle is well preserved and its structure has been ascertained.

The conch was a small orthoceracone with prominent longitudinal ridges. There are fifteen obtusely angular longitudinal ridges on the mold separated by broadly concave grooves. The septa are spaced about 1 mm. apart and are directly transverse with only the very faintest trace of a broad ventral saddle. The siphuncle is orthochoanitic, with exceedingly short septal necks and is situated midway between the center and the ventral surface. It is about one-third mm. in diameter where the shell has a width of a little less than 3 mm. The septa are only moderately convex.

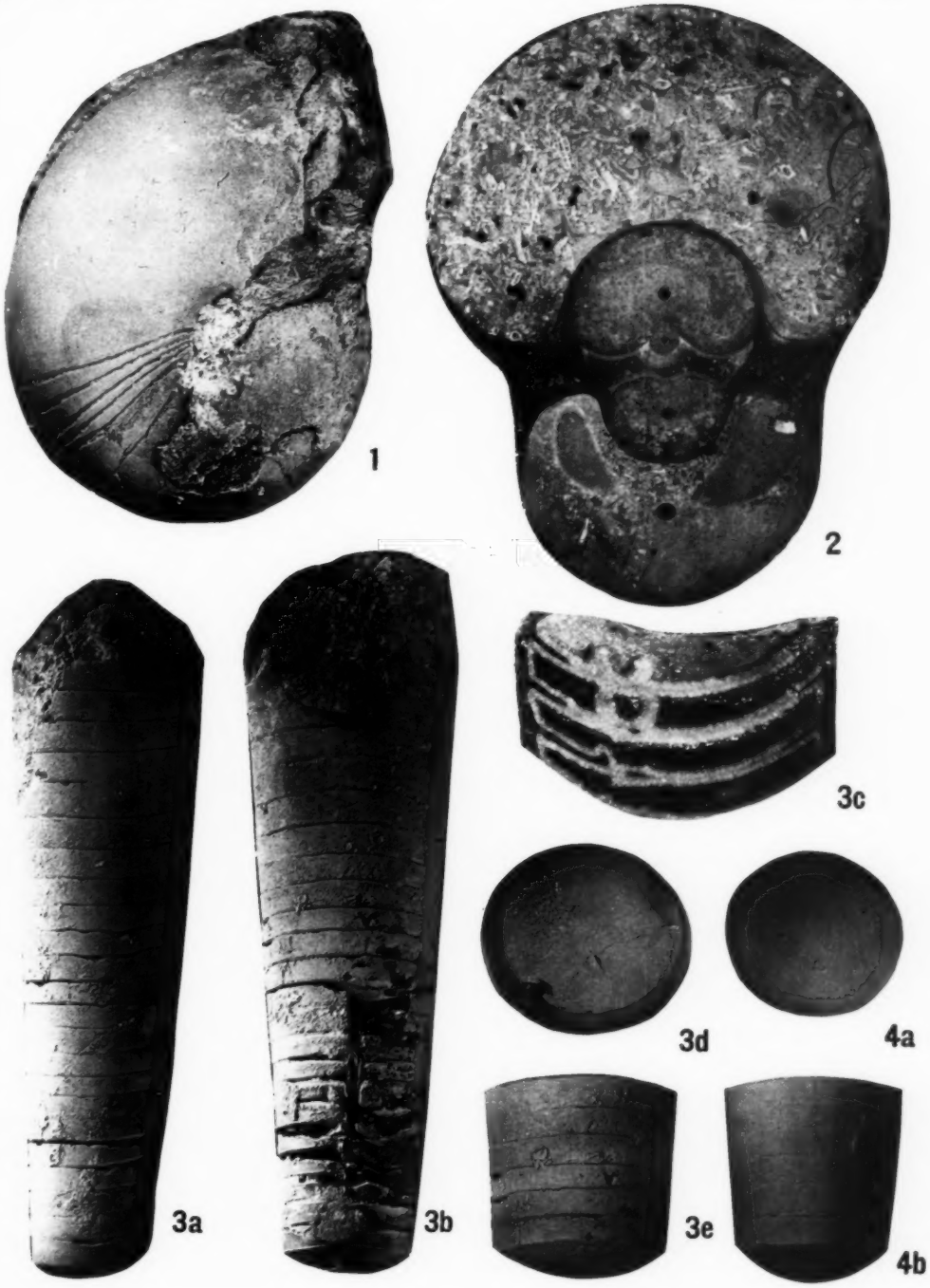
Discussion.—A form similar to this was described by Marie Tzwetaev (1888) from the Lower Pennsylvanian Dewiatowo oolite of Russia under the name *Orthoceras sociale*. The lateral costae of Tzwetaev's species were decidedly nodose, whereas the costae of the specimens at hand are smooth. Possibly the Russian and Kansas forms are representatives of an undescribed genus, inasmuch as typical *Kionoceras* is found in the older Paleozoic.

EXPLANATION OF PLATE 69

FIGS. *1, 2*—*Coloceras milleri* Newell, n. sp. *1*, A small gerontic paratype, from the Farley limestone at De Soto, Kansas, showing the muscle mark just ahead of the last suture, ×1. *2*, Sectioned paratype from the type locality, ×2, showing ontogenetic changes in whorl section; the dark filling within the umbilicus of the outer volution is an umbilical plug. (p. 481)

3a–e—*Mooreoceras condrai* Newell, n. sp. *a*, View of right side of holotype, ×1, from the Farley limestone just east of De Soto, Kansas. *b*, *e*, Ventral view of holotype, ×1, showing characteristic but obscure ventral saddle. *c*, Section of part of holotype, ×2, showing characteristic globular form of the connecting rings in *Mooreoceras*. *d*, Septal view of part of the holotype, ×1, showing the slightly depressed form of the cross-section. (p. 483)

4a, b—*Mooreoceras angusticameratum* Miller, Dunbar, and Condra, ×1. Part of the holotype from the Lower Pennsylvanian Kendrick shale in Kentucky, introduced here for comparison of the septal convexity and outline of the conch; although having a relatively small diameter the mold has its sutures spaced the same distance apart as in the larger *M. condrai*, n. sp. (p. 484)



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Distribution.—The form has been found in the Farley limestone near De Soto, Kansas, and in the Olathe (Stanton) limestone at Fredonia, Kansas.

Genus KONINCKIOCERAS Hyatt, 1883

KONINCKIOCERAS JEWETTI Newell, n. sp.

Plate 72, figures 1*a*, *b*

This species is known from fragmentary internal molds of two specimens. One of these, the holotype, has a diameter of 10.5 cm. including one-third of the penultimate whorl, the last six camerae and a little more than one-third volution of the living chamber. The other specimen, a paratype from the same locality as the holotype, retains part of the living chamber, including nearly one-half of a volution, and a fragment of the penultimate whorl.

The shells are smooth, shallowly impressed nautilicones with depressed whorls, attaining at least two and one-third volutions at a shell diameter of 10.5 in the holotype, and in the other specimen about two volutions at a shell diameter of about 9 cm. Near the end of the first volution the shallow impressed zone makes its appearance. At this stage the whorl section has already started to assume a hexagonal form. The impressed zone is flattened and narrow, about 5 mm. across. The slightly convex umbilical slopes flare outward widely to umbilical shoulders situated slightly dorsad to the middle of the whorl section. The sides, although somewhat convex, are set off by gibbous ventro-lateral and umbilical shoulders from the broadly rounded venter and the dorsum. The venter is slightly narrower than the width of the shell through the umbilical shoulders so that the sides converge slightly toward the venter. The siphuncle at this immature stage is just ventral to the center. The measurements of the whorl section near the end of the first volution in the holotype are:

Measurements of Koninckioceras jewetti
near end of first volution

Width	17.5 mm.
Height	13.0 mm.
Width of impressed zone	5.0 mm.
Diameter of siphuncle	2.0 mm.

The whorls retain the hexagonal form to maturity, becoming, however, slightly more depressed. The siphuncle assumes a position about midway between a central point and the venter. Near the end of the second volution the whorl section in the holotype has the following dimensions:

Measurements of Koninckioceras jewetti
near end of second volution

Width	44.0 mm.
Height	32.0 mm.
Width of impressed zone	16.0 mm.
Depth of impressed zone	2.0 mm.
Diameter of the siphuncle	4.5 mm.
Width of venter, about	34.0 mm.
Height of sides, about	18.0 mm.
Breadth of umbilical slopes	15.0 mm.
Distance between septa on venter	9.0 mm.

The sutures are similar in the last two whorls. They consist of broad ventral and lateral lobes and a deep lobe in the impressed zone. A slight tendency for an increase in convexity at the middle of the lobe in the impressed zone suggests a trace of an annular lobe. The sutures are practically straight on the umbilical slopes, passing obliquely forward, and there are saddles corresponding to each of the angles of the whorl section.

There is no trace of ornamentation other than growth lines at any stage. A broad and relatively shallow hyponomic sinus is indicated, and it is only slightly more convex than the ventral lobes. An obscure ventro-lateral crest occurs on either side of the aperture.

The siphuncle is orthochoanitic with long septal necks. On the ventral side of the siphuncle the necks extend backward about one-third of a camera and they are very slightly curved inward at the tip.

On the dorsal side of the siphuncle the necks are short, extending backward and inward obliquely for a distance of about one-sixth of a camera, also curving inward so that the necks are slightly constricted at the ends. The connecting rings are very long, embracing a septal neck near the base and extending backward within the next septal neck to its distal margin.

Discussion.—Nautiloids commonly referred to *Domatoceras* Hyatt may be divided into two groups. One group, like *Koninckioceras jewetti*, has very broad, transverse whorls. This group includes *K. wyandottense*, n. sp., *Domatoceras militarium* Hyatt, and *D. simplex* Hyatt. The other group, characterized by the genotype *Domatoceras umbilicatum* Hyatt, has high compressed whorls with a narrow, flattened venter. The group having depressed whorls resembles *Koninckioceras*. The genotype species of *Koninckioceras* is inadequately known, however, and until its siphuncular structures are clearly described these Pennsylvanian and Permian species can be referred only provisionally to the Mississippian genus.

Distribution.—The types of *K. jewetti* were found in the upper part of the Spring Hill (Plattsburg) limestone southeast of Garnett, Kansas, in the SE. ¼ sec. 32, T. 21 S., R. 20 E. The species has not been found elsewhere.

KONINCKIOCERAS ELIASI Newell, n. sp.
Plate 72, figure 2; Text-figures 1*a*, *b*

A single specimen of this form was found in the Farley limestone near De Soto, Kansas. It is an internal mold comprising nearly three very slightly embracing volutions of which one-third volution is a remnant of the living chamber. The specimen measures about 10.5 cm. in diameter.

The whorl section appears to be transversely subelliptical throughout the phragmacone. At the adoral end of the phragmacone the umbilical shoulders become less gibbous and indistinct lateral zones appear, giving the whorl section a hexagonal form. Although the younger whorls are essentially elliptical the dorsal area between the umbilical shoulders is somewhat more convex than the broadly rounded venter. In accordance with the rounded whorls the sutures are simple,

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EXPLANATION OF PLATE 70

FIGS. *1*—*Coloceras milleri* Newell, n. sp. View of right side, ×1, of a paratype from Kansas City, probably from the Winterset limestone; the muscle mark is clearly shown near the base of the living chamber extending backward as a muscle track covering the sutures on the lateral zones; the ventral view of this specimen is shown on Plate 68, fig. *3*. (p. 481)

2a–c—*Kionoceras* sp. Fragment from the Farley limestone at De Soto, Kansas, all figures ×8. *a*, Ventral view showing longitudinal ridges, spacing of sutures, and septal convexity of the mold. *b*, Septal view showing shape of section and position of the siphuncle. *c*, Thin-section showing orthochoanitic structure of the siphuncle. (p. 484)

3a, b—*Pronorites kansasensis* Newell, n. sp. *a*, Ventral view of the holotype, ×1, from the Argentine limestone near Welborn, Kansas. *b*, Lateral view of the same, ×1. (p. 488)

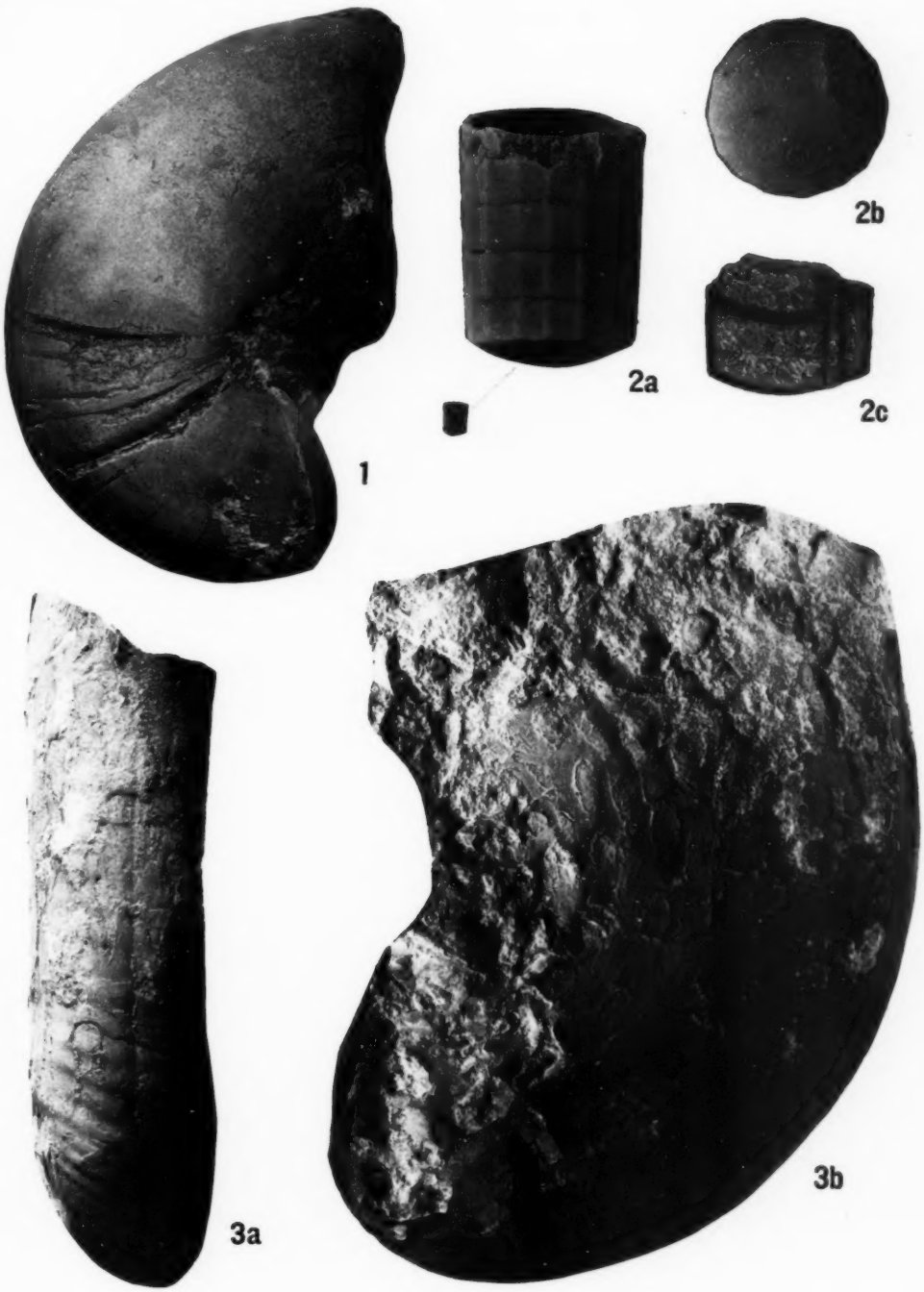
EXPLANATION OF PLATE 71

FIGS. *1a–c*—*Koninckioceras wyandottense* Newell, n. sp. Views of the holotype, ×1, from the Argentine limestone, near Welborn, Kansas. (p. 488)

EXPLANATION OF PLATE 72

FIGS. *1a, b*—*Koninckioceras jewetti* Newell, n. sp. *a*, Septal view of the last septum and part of the penultimate whorl in the holotype, ×1, showing the characteristic whorl section of *Koninckioceras*. *b*, Ventral view of holotype, ×1, from the Plattsburg limestone south of Garnett, Kansas, showing the form of the hyponomic sinus. (p. 485)

2—*Koninckioceras eliasi* Newell, n. sp. Lateral view of the holotype, ×1, from the Farley limestone at De Soto, Kansas. (p. 486)



Newell, Pennsylvanian Cephalopods

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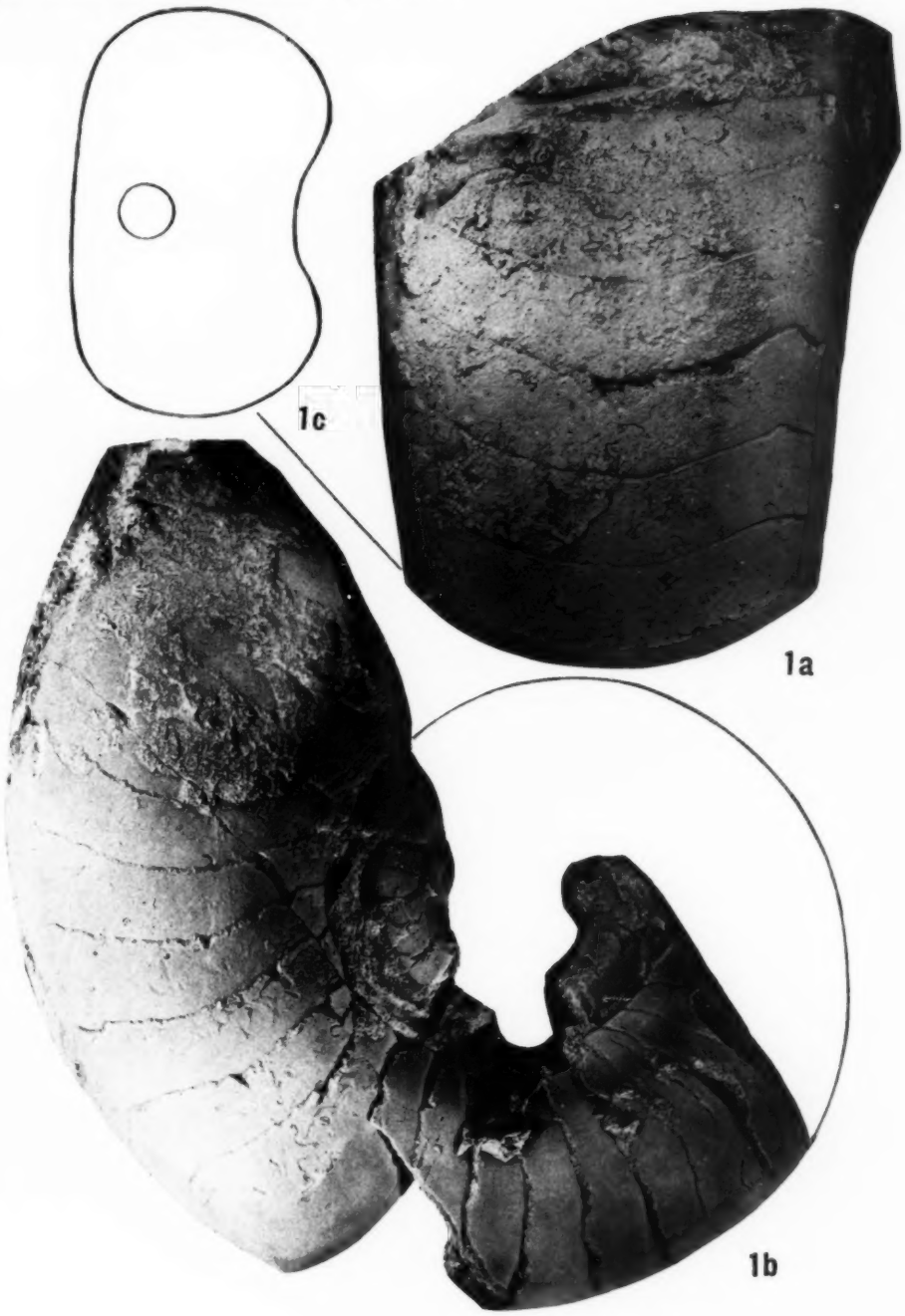

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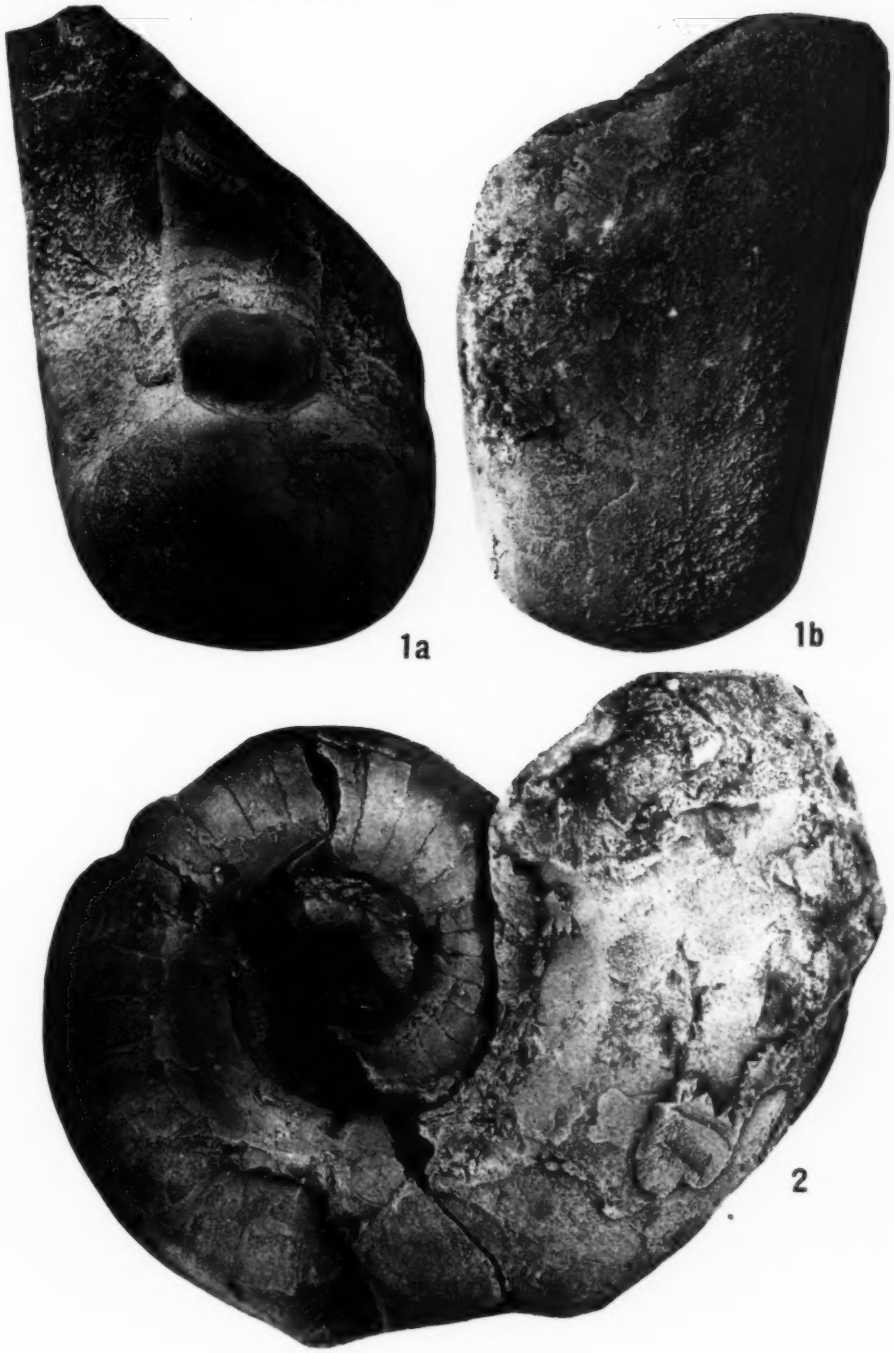

Newell, Pennsylvanian Cephalopods

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comprising a broad shallow ventral lobe and a narrow dorsal lobe in the impressed zone. In the younger stages the sutures are essentially straight and transverse to the whorls across the sides and umbilical slopes. Near the adoral end of the phragmacone, however, in response to the obscure angularity of the whorls faint lateral lobes and obscure ventro-lateral and dorso-lateral saddles appear.

The siphuncle is orthochoanitic and has about the same characters seen in *K. jewetti*. The septal necks are long, extending backward one-third of a camera on the ventral side and about one-sixth of a camera on the dorsal side; they are slightly constricted at the end. The connecting rings are attached at the end of one septal neck, passing through the neck forward and embracing completely the succeeding septal neck in such a manner that the septal necks are covered on the inside and outside by the overlapping ends of the connecting rings. The posterior and ventral parts of the connecting rings are thickened and club-like as seen in section, a feature that is lacking or not well developed in *K. jewetti*. The siphuncle at the adult stage is midway between the central point and the venter.

The measurements of a whorl section at the base of the living chamber in the holotype are given:

Measurements of Koninckioceras eliasi
at base of living chamber

Height	29 mm.
Width at umbilical shoulders	41 mm.
Width of venter, about	35 mm.
Width of impressed zone	17 mm.
Depth of impressed zone	3 mm.
Diameter of siphuncle	4.4 mm.
Space on venter between septa	10 mm.

Discussion.—The species *Koninckioceras eliasi* is similar to *K. jewetti*. The former can be distinguished by the persistence of the subelliptical whorl section and by the simpler and less strongly flexed sutures. The connecting rings in the present species are slightly thickened at their ventral and anterior ends, whereas in *K. jewetti* such a thickening is obscure or absent. These minor characters of the connecting rings may possibly be significant in distinguishing between the two species.

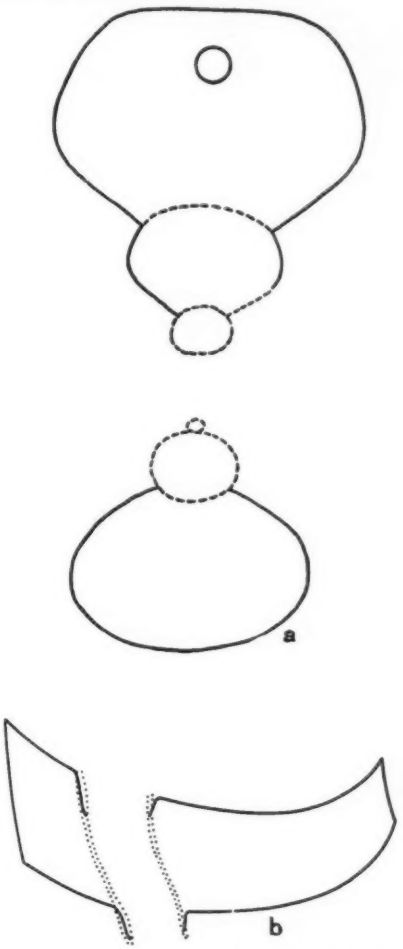

FIG. 1—*Koninckioceras eliasi* Newell, n. sp. *a*, Cross section intersecting the adoral end of the phragmacone, ×1. *b*, Diagram of siphuncular structures near adoral end of phragmacone, ×2.

The species is dedicated to Prof. M. K. Elias of the Kansas Geological Survey.

Distribution.—The holotype was collected by Mr. J. M. Jewett from the

Farley limestone near De Soto, Kansas. The species has not elsewhere been recognized.

KONINCKIOCERAS WYANDOTTENSE
Newell, n. sp.
Plate 71, figures 1*a–c*

The specimen from which the species is known consists of half of each of the last two whorls, retaining a very short and incomplete part of the living chamber.

The conch is relatively large with two and one-half or more slightly embracing whorls. The whorl section in the adult whorl is transversely quadrate, the width of dorsum and venter being subequal. The dimensions of the section at the base of the living chamber in the holotype are given:

Measurements of Koninckioceras wyandottense *at base of living chamber*

Width	65 mm.
Width of venter	58 mm.
Width of dorsum	59 mm.
Width of impressed zone	20 mm.
Height from impressed zone	35 mm.
Diameter of siphuncle	6.5 mm.
Septal spacing on venter	12.4 mm.

At an adult stage the broad ventral lobe has a convexity corresponding to two-thirds the space between two sutures. Broad lobes occupy the sides, leading into slight saddles at the umbilical shoulder and nearly straight, forward directed sutures on the umbilical slope. Deep lobes correspond to the impressed zone. The siphuncle is orthochoanitic and similar in construction and position to that in *Koninckioceras eliasi*.

Discussion.—This species may be distinguished from related forms by the transverse and quadrate whorls. The broadest part of the whorl in this species, unlike similar ones, is at the middle of the lateral zones rather than between the umbilical shoulders.

Distribution.—The single specimen of *K. wyandottense* was found in the upper part of the Argentine limestone at Boyn's quarry northeast of Welborn, Kansas.

FIG. 2—Suture of holotype of *Pronorites kansasensis* Newell, n. sp., ×1.

Genus PRONORITES Mojsisovics

PRONORITES KANSASENSIS Newell, n. sp.
Plate 70, figures 3*a*, *b*; Text-figure 2

This species is based on a single specimen comprised of nearly half a volution of the phragmacone. The conch is relatively large, discoidal, greatly compressed, and deeply involute. Allowing for a slight distortion in the holotype, the sides apparently are flat and essentially parallel. The ventro-lateral areas are broadly rounded to the more convex median part of the venter. The type, which is an internal mold, shows a slight median groove on the venter. On either side of this there are transverse ribs, ten of which occupy a space of about 35 mm. The ribs are not visible on the flattened sides of the shell, and the median groove between them is shallow and less than

1 mm. broad. The maximum diameter of the outer volution can only be estimated, since but half the whorl, lacking the living chamber, remains. The diameter of the shell lacking the living chamber was at least 11.5 cm., and at this diameter the umbilicus is 15 mm. across. The width of the outer whorl is about 30 mm.

Each suture displays a trifid ventral lobe, at least five pairs of lateral lobes and six pairs of saddles. The umbilical and dorsal sutures are unknown. The middle point of the ventral lobe is relatively short, the lateral projections extended, and the lobe basally constricted, so that its whole aspect recalls that of species of *Gastrioceras* rather than *Pronorites*. The first saddle is moderately long and broad, and is club-shaped with a constriction just back of its circular apex. The first lateral lobe occupying the ventro-lateral area is long, so broad and deeply bifid that it constitutes two well-defined adventitious lobes. Each of these is acute and tongue-shaped, and the intervening saddle is moderately narrow, rounded, and not noticeably constricted. The second lateral saddle is broader and fully twice as long as the first saddle and is only slightly and broadly constricted at the middle. The second lateral lobe is markedly unsymmetrical, being obliquely truncated so that the ventral side is the longer. The sides of this lobe are subparallel and gently curved so as to follow the longitudinal axis of the whorl. The apex is at the ventral margin of the lobe. The first auxiliary saddle is only two-thirds as long as the second lateral and is essentially unconstricted. There are three and perhaps four auxiliary lobes similar to the second lateral lobe which decrease toward the umbilicus, and there are three more auxiliary saddles similar to the first auxiliary saddle. These likewise decrease dorsally.

Discussion.—This species could scarcely be confused with any other Pennsylvanian *Pronorites*. It is similar to *P. pseudotimorensis* Miller in having its second lateral saddle much longer than the third (first auxiliary) and by the circumstance that the third (first auxiliary) lobe projects slightly farther posteriorly than the second lateral lobe. It can be distinguished by its angular lobes, by the elongate lateral elements of the median lobe, and by the very deeply bifid first lateral lobe. Furthermore, the Kansas species is much larger and is ornamented with transverse ribs on the venter. This is probably the largest known species of the genus.

Distribution.—The only known specimen was collected by Mr. J. M. Jewett at the top of the Argentine limestone at Boyn's quarry, northeast of Welborn, Kansas.

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NORMAN D. NEWELL, UNIVERSITY OF KANSAS, LAWRENCE, KANSAS. MANUSCRIPT RECEIVED BY THE EDITOR, DECEMBER, 1935.

JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 6, PP. 490–496, PL. 73, TEXT-FIGS. 1–6,
SEPTEMBER, 1936

A SPECIES OF THE AMMONOID GENUS *ARTINSKIA* FROM THE LOWER PERMIAN OF KANSAS

A. K. MILLER

ABSTRACT

A new species of the ammonoid genus *Artinskia*, a medlicottid, is described from the Florena shale of the Big Blue series, Lower Permian, in southern Kansas. Congeneric forms have been found in the Middle Permian (Artinskian and Bitauni) of the Ural Mountains and Timor and in the Lower Permian (Uralian and Wichita) of the Urals and Texas. Peculiarly enough, the Lower Permian forms, now known from three widely separated localities, are considerably older stratigraphically than any known representative of *Propinacoceras*, the supposed ancestor of *Artinskia*.

Some time ago R. A. Whortan of Wichita, Kansas, found a medlicottid cephalopod in the Florena shale of southern Kansas. He loaned it to N. D. Newell of the Kansas Geological Survey, who with his colleague, M. K. Elias, recognized that it represented the genus *Artinskia* and sent it on to me for study.

The Florena shale, which prior to 1904 was known in Kansas as the Cottonwood shale, is a thin persistent member of the Beattie formation, extending from Nebraska across Kansas into Oklahoma with a thickness varying between 3 and 13 feet. It rests directly on the Cottonwood limestone, which for a long time was regarded as the base of the Permian in the northern Mid-Continent region—the Pennsylvanian-Permian boundary is now generally drawn at the unconformity below the Admire shale, some 300 to 400 or more feet below the Cottonwood, and this procedure places the Florena somewhat below the middle of the Lower Permain or Big Blue series. Only a very few medlicottids are known from the Lower Permian and this specimen is the first one to be found in the northern Mid-Continent region; therefore, it is perhaps more than ordinarily significant and it merits a great deal of consideration. I have gone carefully over the literature which deals with related forms and have spent considerable time studying the specimen in detail. Although I am not entirely satisfied with the conclusions reached, I believe that they are as nearly accurate as the present state of our knowledge of these peculiar ammonoids and the beds which contain them permit.

In his well known monograph on the ammonoids of the Artinskian beds Karpinsky (1889) suggested that the medlicottids known at that time (exclusive of *Propinacoceras*) could be divided into three sections: 1, the group of *M. primas* (Waagen); 2, the group of *M. artiensis* (Grünewaldt); and 3, the group of *M. wynnei* Waagen. The first of these groups is typified by the genotype of *Medlicottia* and it therefore retains Waagen's generic name. Noetling

(1904) coined the generic name *Episageceras* for the third group, and later Karpinsky (1926) proposed to recognize the second also as a distinct genus, *Artinskia*. Karpinsky referred to *Artinskia* only one species, *Goniatites artiensis* Grünewaldt, and it is, therefore, the genotype. However, *Goniatites artiensis* Grünewaldt apparently is a synonym of *Goniatites falx* Eichwald, which has priority, and, therefore, the type species of *Artinskia* should be called *A. falx*, not *A. artiensis*.

It has been recognized for some time that this species, *A. falx*, is more or less intermediate between the genotype of *Propinacoceras*, *P. beyrichi* Gemmellaro of the Middle Permian Sosio beds of Sicily, and the genotype of *Medlicottia*, *M. primas* (Waagen) of the Upper Permian Upper Productus limestone of the Salt Range in India (see text-figs. 2, 5, and 6). These three genotypes, as well as those of *Uddenites* and *Episageceras*, differ so much from one another that no two of them should probably be regarded as congeneric. However, when we attempt to place the rest of the known medlicottid species in the genera represented, we find that many of them are distinctly intermediate between these genotypes and others are more or less aberrant. It is, therefore, not surprising that Karpinsky, Noetling, Diener, Haniel, and J. P. Smith have differed markedly in regard to the affinities of certain of these medlicottids. Although I am somewhat diffident about expressing an opinion in regard to such a complicated, moot question until I have had an opportunity to study more material, it now seems to me that tentatively at least it will be well (1) to leave in *Uddenites* only its genotype, *U. schucherti* Böse; (2) to refer to *Propinacoceras* the rest of the medlicottid species in which the flanks of the ventral lobe of the sutures are not serrate and the ventro-lateral zones of the conch are nodose; (3) to place in *Artinskia* those species in which only the adoral portions of the flanks of the ventral lobe are serrate and the ventro-lateral zones of the conch are nodose; and (4) to assign to *Medlicottia* s. s. and *Episageceras* the medlicottids in which the flanks of the ventral lobe are serrate throughout most of their length and the ventro-lateral zones of the conch are in most cases non-nodose. *Episageceras* differs from *Medlicottia* s. s. particularly in that the ventral side of the conch of the former is relatively broad and flat whereas that of the latter is concave and is bordered by sharp ventro-lateral keels.

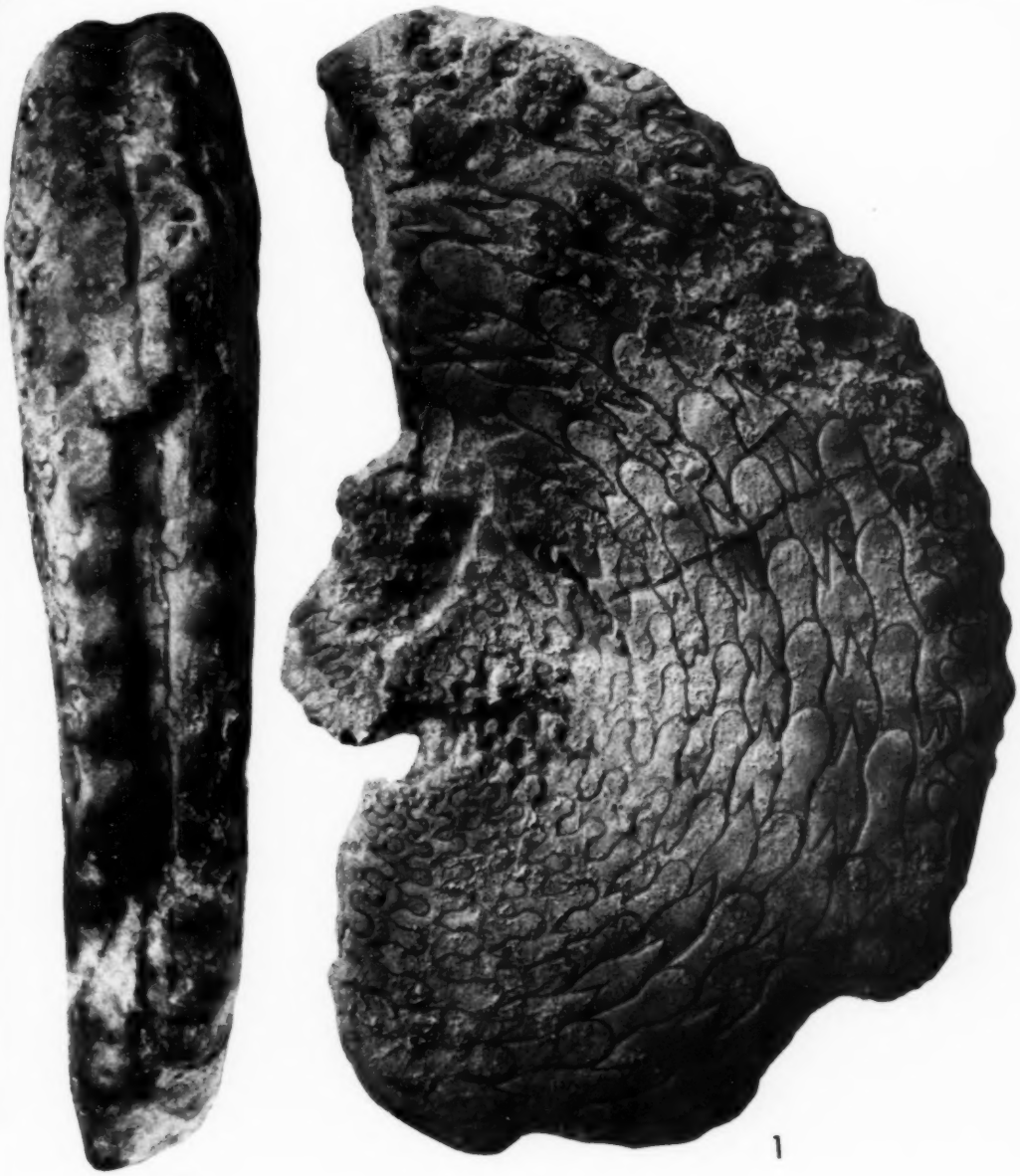
As thus interpreted, the genus *Artinskia* includes, besides its genotype, the following described species: *Propinacoceras transitorium* Haniel and *Medlicottia artiensis timorensis* Haniel (a distinct species), both from the Bitauni beds of Timor; probably *Medlicottia magnotuberculata* Tchernow of the Artinskian beds of the Ural region (of which the sutures are not known); and the form from the Wichita group of north-central Texas which Böse (1917) described as "*Medlicottia* n. sp. (aff. *M. artiensis*)," which is probably the same as

the form from the Admiral formation of the Wichita-Albany group that is designated *M. adkinsi* on a "Geologic section of the Permian and Pennsylvanian formations of north-central Texas," recently issued by the Texas Bureau of Economic Geology in the form of a blueprint chart. Both of the Timor forms are Middle Permian in age and most of the known representatives of *A. falx*, the genotype, also came from the Middle Permian (Artinskian). The Texas representatives, however, came from the Lower Permian, and Fredericks (1921) has described an incomplete specimen from the Lower Permian (Uralian) of the Ural Mountains that apparently represents *A. falx*—at any rate, the portion of the sutures of this specimen that Fredericks was able to make out is precisely similar to that of undoubted representatives of *A. falx*.

It has been generally believed that *Artinskia* arose from *Propinacoceras* but since *Propinacoceras* has never been found below the Middle Permian, it is difficult to understand how it could be ancestral to *Artinskia* which is widespread in the Lower Permian. Either our collections are very incomplete, and we may expect to find *Propinacoceras* in beds which are as old or older than those which carry *Artinskia*, or our ideas in regard to the phylogeny of the medlicottids (or the relative age of the containing beds) are erroneous. J. P. Smith (1927) expressed the belief that a complete revision of the medlicottids, exclusive of *Uddenites* and possibly *Propinacoceras* "would show that they are all only sections or subgenera of *Medlicottia*, and have no stratigraphic significance, and that the characters chosen for distinguishing them are purely artificial, sometimes even imaginary." It seems to me that these conclusions are hardly justified by the available information and that they are more than necessarily pessimistic. That is, I am inclined to believe that at present we happen to be in the rather awkward position of having sufficient data to show that generally accepted beliefs in regard to either the phylogeny or the chronology of the medlicottids are in part erroneous, but at the same time our knowledge is not sufficient to enable us to determine with precision just where the errors lie. This situation will almost certainly disappear when more and better specimens have been collected and studied, and I believe that eventually we will find that the medlicottids have a great deal of stratigraphic value and that they can be readily divided into monophyletic genera. Of course, it is rather disconcerting to find representatives of a highly developed genus (*Artinskia*) occurring much lower stratigraphically than its supposed progenitor (*Propinacoceras*). Nevertheless, we must take cognizance of the fact that undoubtedly a long period of time elapsed between the deposition of the

EXPLANATION PLATE OF 73

FIGS. *1, 2*—*Artinskia whortani* Miller, n. sp. Lateral and ventral view of the holotype, ×3, from the Florena shale of southern Kansas. (p. 493)



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Miller, Permian Ammonoid

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Upper Pennsylvanian beds in which all known representatives of *Uddenites* have been found and the deposition of the Middle Permian beds that have yielded all known representatives of its supposed descendant, *Propinacoceras*. It does not seem probable that *Artinskia* developed directly from *Uddenites*, or a similar form, without passing through a *Propinacoceras* stage, but it is more likely that much of the evolution of the medlicottids took place earlier than we have been wont to believe, that primitive forms continued to exist along side of their more advanced progeny, and that periodically the different groups, irrespective of their degree of development, found optimum living conditions and flourished in such numbers that we have been able to discover their remains—after all, it is remarkable that we find as nearly complete sequences as we do, not that we do not find more nearly complete ones.

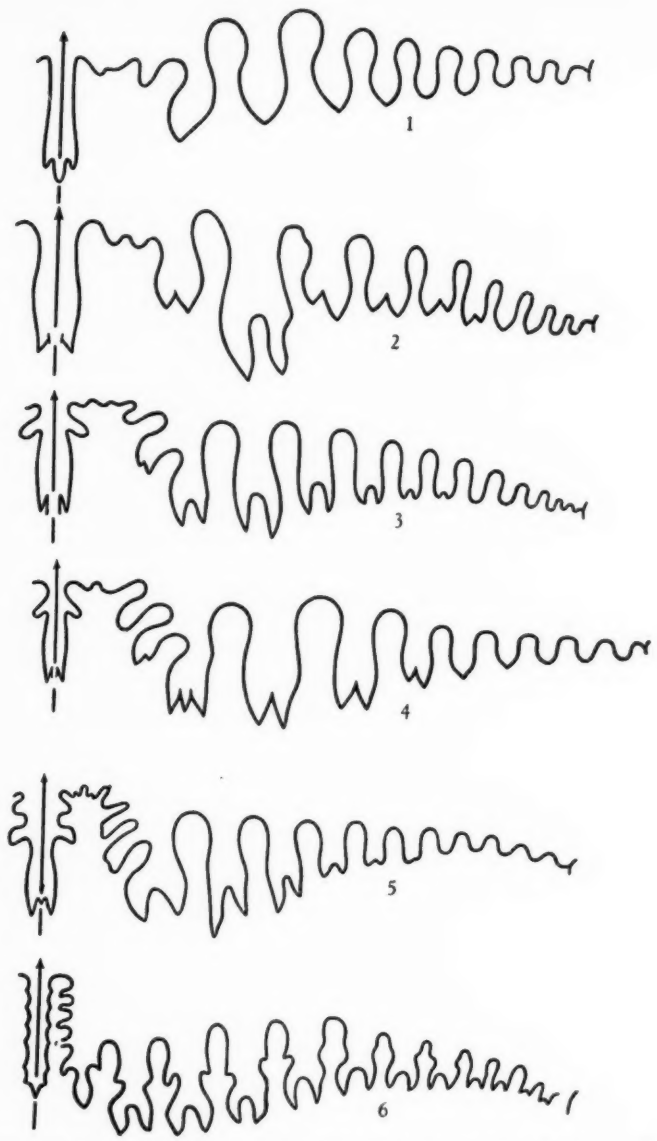
Genus ARTINSKIA Karpinsky, 1926

ARTINSKIA WHORTANI Miller, n. sp.
Plate 73, figures 1,2; Text-figure 4

Conch discoidal, ammoniticonic, and moderately large—the preserved part of the holotype and only known representative of this species, which is septate throughout and therefore represents only phragmacone, attained a maximum diameter, measured across the umbilicus, of 55 to 60 mm. Whorls strongly compressed, flattened laterally, abruptly rounded ventro-laterally, grooved ventrally, and deeply impressed dorsally; the lateral sides of the conch are nearly parallel and converge only slightly toward the venter. The whorls are about one-third as wide as high and near the adoral end of the holotype the maximum width and height of the conch measure about 11 mm. and 34 mm., respectively. The width of the ventral side of the conch is equal to only about two-thirds the maximum width of the whorl, and at the adoral end of the holotype the ventral side of the conch is about 7½ mm. wide and the median groove in it is a little more than 2 mm. wide and approximately 1 mm. deep. The umbilicus is closed or nearly so, and the umbilical shoulders apparently are low and inconspicuous; however, it should be understood that the umbilical portions of the holotype are very poorly preserved.

Each ventro-lateral shoulder of the conch is marked by a single row of low rounded moderately prominent nodes, of which there are about sixteen on the adoral quarter-volution of the holotype. These nodes are not arranged in pairs, but nodes on opposite sides of the conch appear to alternate in position. The ventral portion of the lateral sides of the conch bears short ribs which appear to be lateral extensions of the ventro-lateral nodes and are rather inconspicuous on the internal mold, at least.

Septa numerous and closely spaced—there are about seventeen in the half-volution of the conch represented by the holotype. Because of the close spacing of the septa, the second and third lateral lobes of the sutures are in contact with the saddles of the preceding sutures. Internal sutures not known, but at maturity each external suture forms a moderately long and narrow ventral lobe and on either side of it nine primary lobes and ten primary saddles. The ventral lobe is unequally but symmetrically trifid at its adapical end; its sides are nearly parallel; and near its adoral end there is on each of its flanks a small rounded adventitious lobe. The first lateral saddle is broad and deep and very asymmetrical; in its adoral extremity there are two small rounded adventitious lobes next to the adventitious lobe on the flank of the ventral lobe; on its dorsal (umbilical) side or flank there are three prominent deep rounded club-shaped almost paral-



FIGS. *1–6*—Enlarged diagrammatic representations of mature external sutures of: *1, Uddenites schucherti* Böse, the genotype of *Uddenites*, from the Upper Pennsylvanian Gaptank formation of western Texas; *2, Propinacoceras beyrichi* Gemmellaro, the genotype of *Propinacoceras*, from the Middle Permian Sosio beds of Sicily; *3, Artinskia transitoria* (Haniel) from the Middle Permian Bitauni beds of Timor; *4, Artinskia whortani* Miller, n. sp., same specimen as Pl. 73, figs. 1, 2, ×2⅞, from the Florena shale of southern Kansas; *5, Artinskia falx* (Eichwald), the genotype of *Artinskia*, from the Middle Permian Artinskian beds of the Ural Mountains; and 6, *Medlicottia primas* (Waagen), the genotype of *Medicottia*, from the Upper Productus limestone of the Salt Range in India. Figure 1 is adapted from J. P. Smith, 2 from Gemmellaro, 3 from Haniel, 5 from Karpinsky, and 6 from Waagen.

lel adventious saddles, and these are separated by two adventitious lobes, the adapical one of which is asymmetrically bifid. The first lateral lobe, which is considerably deeper than the ventral lobe, is asymmetrical and it is trifid. The second lateral saddle and all of the rest of the saddles in the external suture are undivided, rounded, and more or less club-shaped. The third lateral (or first auxiliary) saddle is slightly larger and higher than the preceding one, but all of the other primary saddles decrease in size progressively toward the umbilicus. The second lateral lobe is large and is distinctly deeper than any of the other lobes of the sutures; it is in contact with the saddles of the preceding suture for about one-third of its length; it is more or less club-shaped but is bifid. The third lateral (or first auxiliary) lobe is similar to the second but is smaller, and it only touches the saddles of the preceding suture. The fourth lateral (or second auxiliary) lobe is similar but is considerably smaller and is distinctly asymmetrical as its ventral prong is much shorter than its dorsal (umbilical) prong. All of the rest of the auxiliary lobes are undivided, and they become progressively smaller toward the umbilicus; they are all more or less pointed but they become progressively more nearly rounded with increasing distance from the venter. Siphuncle ventral and marginal in position—it appears to be in contact with the test or nearly so.

Remarks.—The sutures of this species indicate that it is the most primitive representative of the genus known. It is strikingly similar to *Artinskia transitoria* (Haniel) of the Middle Permian Bitauni beds of Timor (compare text-figs. 3 and 4), but it differs from that species particularly in that at maturity its sutures form fewer lobes and saddles, only two (rather than four) of its auxiliary lobes are bifid, there are only two (rather than three) adventitious lobes in the top (adoral portion) of the first lateral saddle of this species, and the first lateral lobe of *A. transitoria* is bifid whereas that of *A. whortani* is trifid. No other congeneric form is known that has a trifid first lateral lobe. The sutures of *A. timorensis* (Haniel) and *A. falx* (Eichwald) are distinctly more advanced than are those of *A. whortani* and they form more adventitious and more auxiliary lobes (compare text-figs. 4 and 5). In the sutures of the *Artinskia* which Böse described from the Wichita group of Texas, three (rather than two) of the auxiliary lobes are bifid and the first lateral lobe is bifid (rather than trifid). No illustrations of this species have ever been published and, therefore, detailed comparisons are not possible.

Occurrence.—The holotype and only known representative of this species came from the Florena shale of southern Kansas, 100 yards east of the Cowley County line, north of the highway; that is, from the northwest corner of sec. 15, T. 31 S., R. 8 E.

Holotype.—Univ. of Kansas, No. 196.

ADDENDUM

Since this paper was written, Toumansky (Permian ammonoids of the Kubergandy River, 1935, pp. 89–91, 119, text-fig. 19, pl. 1, figs. 8–10) has described and illustrated a new species of *Artinskia, A. dutkevitschi,* from the Middle Permian (Word equivalent) of the Pamirs of central Asia, and in 1933 Heritsch (*Mitt. Naturwiss. Ver. Steiermark*) described a worn fragmentary specimen from the white Trogkofel limestone of the Carnic Alps as *Medlicottia artiensis* var. *carnica.* In so far as I can tell from the published data, both of these forms are probably referable to the genus *Artinskia,* but neither of them seems to be very close to *A. whortani,* described above.

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MIDDLE EOCENE FORAMINIFERA FROM THE LLAJAS FORMATION, VENTURA COUNTY, CALIFORNIA

J. A. CUSHMAN and J. H. McMASTERS

ABSTRACT

Strata cored in a well on the north side of Simi Valley, Ventura County, California, are correlated on the basis of stratigraphic position, paleontology, and lithology with the Llajas formation, of middle Eocene age, exposed 2 miles east of the well. Core samples from the well furnished most of the species of foraminifera described and figured herein.

On the northeastern side of Simi Valley, Ventura County, California, in Las Llajas Canyon, is a well exposed section of conglomerate grading upward into oily silty sands which are overlain by approximately 1,600 feet of sandy shales and siltstone. This section comprises the Llajas formation, of middle Eocene age. In referring to middle Eocene, no implication is here made that the Llajas formation is correlated with Lutetian stage of the Paris Basin, although the two may be about the same age. Exact intercontinental synchronizations cannot now be made either with the marine invertebrates or with the terrestrial mammals.

The Richfield Oil Company of California, in 1930, drilled a well, Tapo No. 42, in Tapo Canyon, 2 miles west of Las Llajas Canyon. After passing from the surface through 260 feet of coarse sandstone, the drill penetrated 2,035 feet of fossiliferous marine siltstone underlain by petroliferous shaly sandstone and stopped in conglomerate at a total depth of 2,417 feet. Cores were taken almost continuously from a depth of 260 feet to bottom and yielded an abundant fauna of mollusks and foraminifers.

Foraminifera occur in outcrops of the Llajas formation, but they are poorly preserved and have not been described heretofore. Since the siltstone, oily sands and conglomerate drilled in Tapo No. 42 are clearly the correlative of the same beds comprising the Llajas formation in Las Llajas Canyon and yield abundant foraminiferal assemblages, which are better preserved than in the surface outcrops, species of Llajas age from the well cores are here figured and described.

Acknowledgments.—We wish to thank Mr. L. E. Porter, chief geologist of the Richfield Oil Company, for contributing the core samples from Tapo No. 42 and for other courtesies. Preliminary examination of the cores was carried on in the Micropaleontology Laboratory at Stanford University and we are indebted to Dr. Hubert G. Schenck for his many helpful suggestions. Assistance in the field was also given by Mr. T. F. Stipp and Mr. Frank Tolman. Some crustaceans were kindly identified by Miss Mary J. Rathbun of the United States

National Museum, where the specimens are deposited, and we are indebted to Dr. Charles Merriam of Cornell University for his identification of a group of specimens of *Turritella*.

of Simi Valley, in the southwestern corner of the Santa Susana Quadrangle. The accompanying stratigraphic sections (fig. 2) were com-

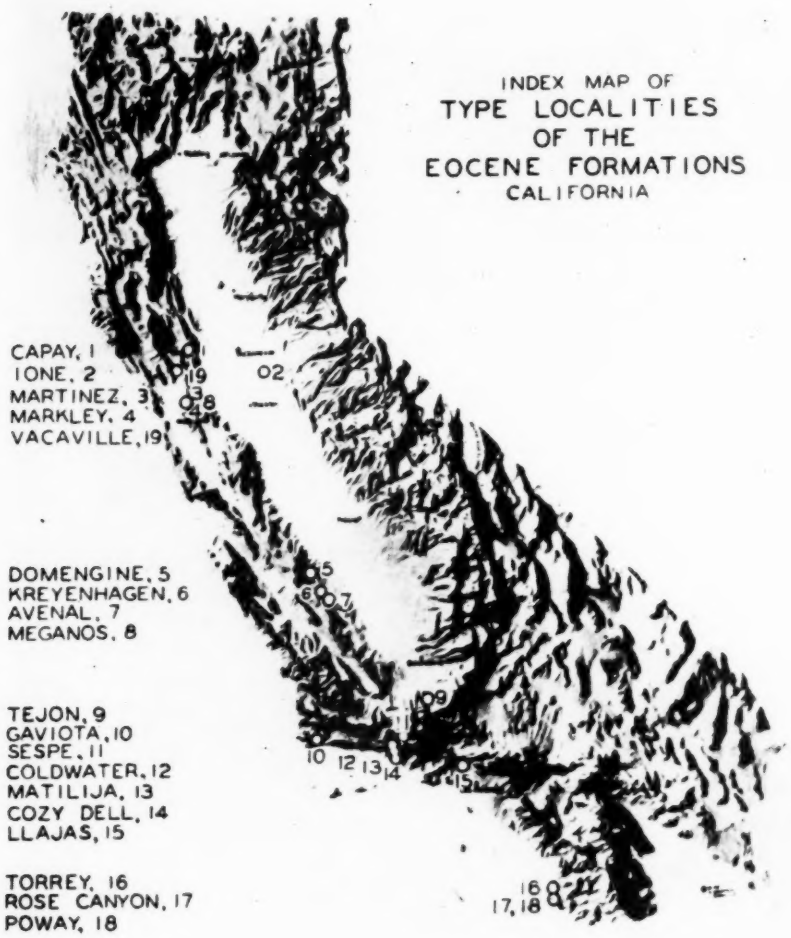

FIG. 1—Index map showing type localities of the more frequently discussed Eocene formations of California.

THE LLAJAS FORMATION

The area under discussion, the vicinity of the mouth of Las Llajas Canyon, lies in the northeastern part

piled from our studies and from the three principal papers dealing with the northeastern portion of the valley. A review of the stratigraphy of

this area is presented in a paper by Schenck (1929, p. 22). W. P. Woodring (1931) has also devoted considerable study to the northeastern side of Simi Valley, but the only published report of his work is a brief note.

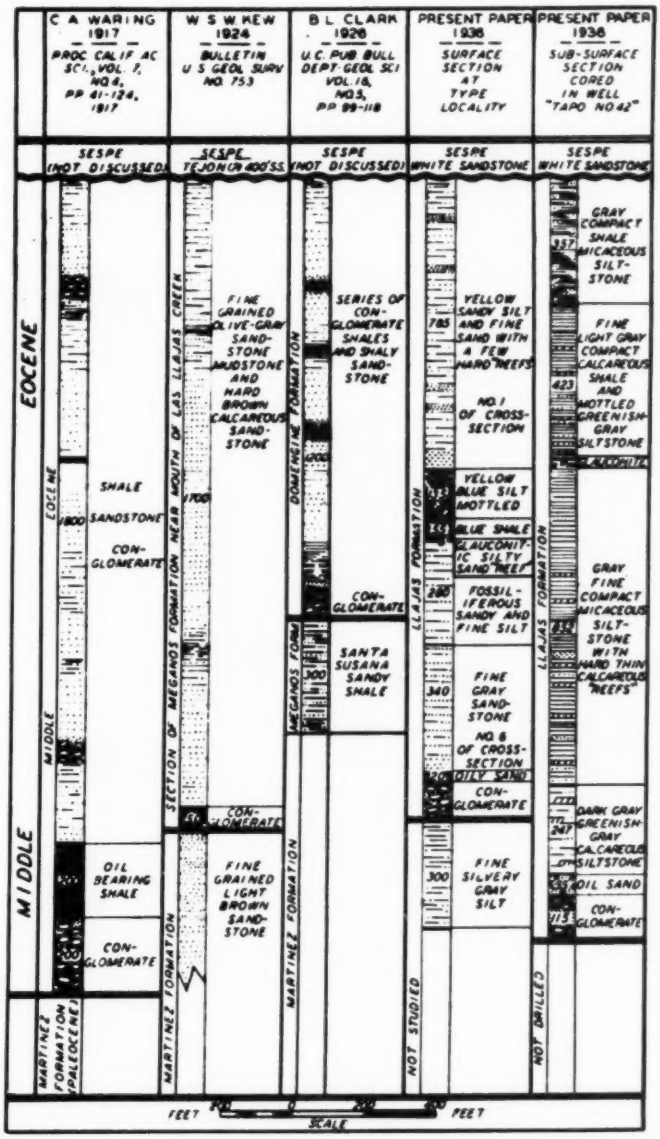

FIG. 2—A comparison of stratigraphic sections by various authors of the Llajas formation in the vicinity of the type locality.

The name Llajas was originally used informally to designate the series of conglomerate, fine sand and sandy siltstone underlying the Sespe formation and outcropping at and in the vicinity of the mouth of Las Llajas Canyon. In the same informal manner it first appeared in the literature as a footnote in a paper by Schenck (1931, p. 455, footnote 50). A formal definition and a designation of the type locality was later given by McMasters (1933).

Type locality.—The Llajas formation is typically exposed in several short ampitheaters eroded in the northwest side of the north branch of Las Llajas Canyon, immediately northwest of the mouth of the latter. This north branch is locally known as Oil Canyon from the presence in it of several small oil seeps near the point where the ampitheaters debouch into the main drainage. These amphitheaters are indicated on the accompanying map (fig. 4) as L. S. J. U. Localities 1094, 1095, 1096, 1968 and 1969 and are described in the list of collecting localities.

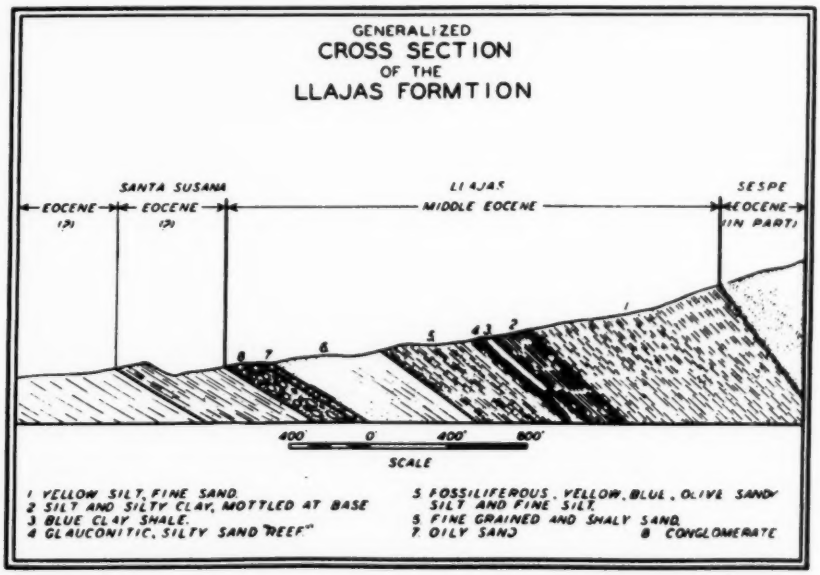

FIG. 3—A generalized cross-section of the Llajas formation at the type locality.

Beds exposed at these localities afford a complete unfaulted section of the Llajas formation. Elsewhere in the vicinity the structure is complicated by faulting and the stratigraphic position of outcropping beds is not always certain.

Following is a brief description of the section exposed at the type locality from the overlying Sespe to the silts underlying the conglomerate at the base of the Llajas. The section is shown graphically in figure 3.

Section of the Llajas formation at the type locality

	Thickness Feet
Sespe formation, Eocene (in part)	
White, fine to coarse sand, occasionally cross-bedded, with some white siltstone and gravel. At the contact is massive, yellow, limonitic-stained poorly sorted, coarse quartz sandstone, which rests unconformably on underlying sediments. This part of the Sespe is identified as late Eocene by Stock (1931) who advances evidence to show that the lower Sespe mammals are late Eocene in age and that the faunules from somewhat higher are early Oligocene.	
Llajas formation (middle Eocene)	
Sandy, limonitic-stained siltstone and fine sandstone, thin-bedded to laminated, tinged with red and somewhat clayey at base. Few thin, hard brown "reefs" containing mollusk fragments	100
Massive, fine silty yellow sand	50
Thin-bedded, predominately yellow, sandy siltstone with few fossils (*Corbula, Cylichnina*)	180
Brown, yellow weathering, fine clayey siltstone, crisscrossed in lenticular fashion by abundant thin laminae of fine, limonitic yellow siltstone	150
Fine, yellow, micaceous siltstone containing a few thin, hard brown siltstone "reefs" with mollusk fragments	305
Yellow, clayey siltstone mottled with an abundance of small, dark-gray cylindrical silt inclusions, possibly the result of borings of marine worms	40
Somewhat nodular, blue and yellow silty clay	10
Massive, medium-grained, friable yellow sand	5
Thin-bedded, yellow sandy siltstone	50
Dull olive-colored silty shale	30
Flaky weathering blue clay shale, containing abundant *Amphistegina californica* Cushman and M. A. Hanna, and *Discocyclina cloptoni* Vaughan, together with other Foraminifera, and an individual coral, *Trochocyathus striatus* (Gabb), in abundance	55
Brownish-green, glauconitic sandy siltstone "reef," hard and fractured. Contains the coral ? *Archohelia clarki* Vaughan	5
Dull-olive and blue, micaceous sandy siltstone	25
Brown, fractured, glauconitic sandy siltstone "reef"	5
Yellow, blue, and dull-olive micaceous fine siltstone and sandy siltstone with very frequent hard calcareous "reefs" carrying an abundance of molluscan fossils, especially *Turritella lawsoni* Dickerson	250
Fossiliferous, yellowish, dark-gray, and green-gray fine sand and shaly sandstone. Differential erosion produces ledges in the beds, none of which is more than 2 feet thick	340
Gritty, dark-gray, oil-stained fine sand, massive and friable, with some conglomerate and an abundance of small fossil fragments	20
Indurated conglomerate composed of large, well-rounded boulders interstratified with beds of yellow and gray oil-stained sand. The contact of the conglomerate with the underlying silts is doubtfully disconformable	100
Santa Susana, Eocene(?)	
Hard, fine, gray sandy siltstone and sands which show very prominently the "mottled" character, attributed to marine worms, described in the 40-foot zone 785 feet below the top of the Llajas. At approximately 300 feet below the conglomerate, the formation becomes flaky, blue-gray, micaceous clayey fine siltstone. These beds between the conglomerate and flaky siltstone are thought to be of Eocene age. They were called the Santa Susana formation by Clark (1926) and were correlated with the Meganos.	

Fauna of the Llajas formation.—The Llajas formation carries marine fossils throughout, but the strata between the conglomerate and the top of the blue shale 920 feet below the top of the formation are especially fossiliferous, yielding many mollusks and a few species of Foraminifera, which are abundant in certain beds, but not well preserved. Several thin "reefs" between the blue shale and conglomerate, beginning 25 feet below the uppermost glauconitic bed and extending down to about the same distance above the conglomerate, contain very abundant specimens of *Turritella lawsoni* Dickerson. These *Turritella* "reefs" are not found above the blue shale. *Turritella*

meganosensis Clark and Woodford, n. subsp. (Merriam, Ms.) was found in the basal conglomerate. Other mollusks include such genera as *Ectinochilus*, *Ficopsis*, and *Galeodea*.

Age and correlation.—Most recent literature has referred the strata of the Llajas formation to the "Domengine" (middle Eocene) in accordance with Clark's (1926) correlation. Hanna (1927, p. 257) has correlated them with his La Jolla formation (middle Eocene) and Stewart (1926, p. 301) has also noted the similarity of faunas from the two localities.

Recent investigations lend assurance to the belief that the Llajas formation is older than the type Tejon formation, the Poway conglomerate, and the Markeley sandstone, and to the conviction that the Llajas is younger than at least the *Turritella meganosensis* beds of the type Meganos formation.

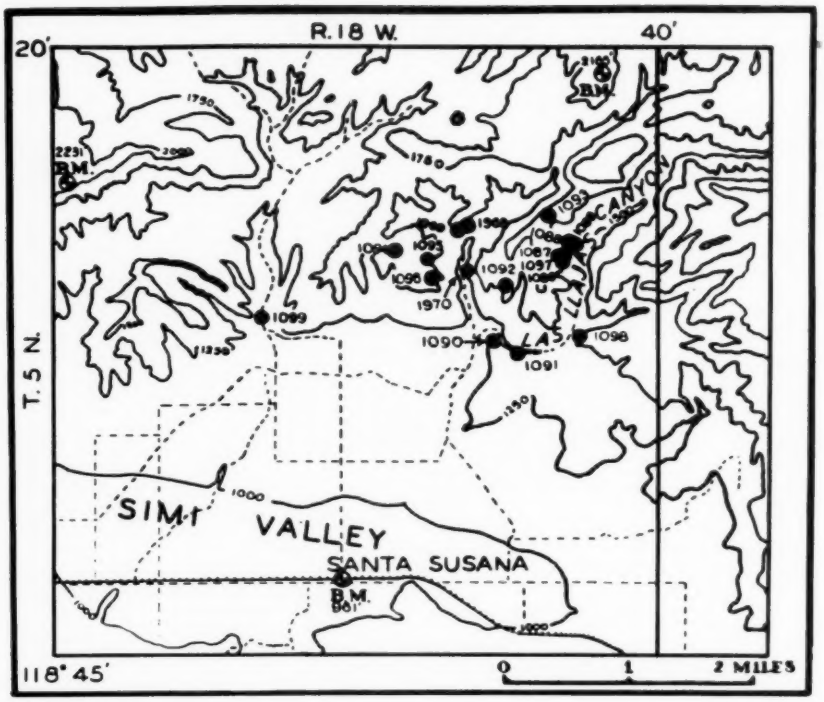

FIG. 4—Sketch map of the northeastern side of Simi Valley, showing collecting localities.

Areal extent of the Llajas formation.—The Llajas formation at the type locality is exposed by the truncation of an anticline, the axis of which trends northeast-southwest and plunges in the latter direction. East of the type locality, erosion of the Llajas and subjacent formations has exposed massive, hard brown sandstone of Cretaceous age. To the

southwest, due to the plunge of the anticline, the Llajas is covered entirely by the Sespe formation. However, wells of the Richfield Oil Company of California, drilled in Tapo Canyon 2 miles west of the mouth of Las Llajas Canyon, have penetrated the Sespe and cored the underlying siltstones, fine sands, and conglomerate of the Llajas formation.

Section of Beds Penetrated in the Tapo No. 2 Well

Lithology	*Logged depth, feet*	*Corrected thickness, feet*
Sespe formation (drilled)		
Coarse white sand.	0– 260	243
Llajas formation		
Gray micaceous siltstone.	260– 604	323
Gray compact shale.	604– 640	34
Fine, gray, "mottled" siltstone.	640– 910	254
Light-gray, compact calcareous shale.	910– 930	19
"Mottled" greenish-gray siltstone.	930–1,040	140
Dark-gray, micaceous fine siltstone.	1,040–1,050	10
Same with some small rounded grains of glauconite.	1,050–1,070	9
Gray, very fine, compact, calcareous shale becoming sandy toward bottom	1,070–1,156	81
Gray, finely micaceous siltstone.	1,156–1,200	42
Greenish-gray partially "mottled" siltstone.	1,200–1,218	17
Gray, micaceous siltstone and fine siltstone with occasional hard, compact, thin calcareous "reefs."	1,218–1,975	712
Dark-gray to greenish-gray, calcareous fine siltstone with occasional hard, thin, silty, calcareous "reefs."	1,975–2,237	247
Logged as petroliferous shaly sand.	2,237–2,295	55
Logged as conglomerate (drilled).	2,295–2,417	115

One of these wells is Tapo No. 42, located in sec. 36, T. 3 N., R. 18 W., San Bernardino B. and M., 1,392 feet north from the southeast corner of and along the east boundary of Tapo Ranch, thence west 340 feet at right angles to the east line.

CORE SAMPLES OF LLAJAS BEDS

Microscopic study of the cores taken in the Tapo No. 42 well from the Sespe-Llajas contact at 260 feet to bottom at 2,417 feet, together with the drilling log of the well, gave the following section, thickness being corrected for an estimated dip of 20 degrees.

All of the siltstone is micaceous and contains considerable carbonaceous matter. The infrequency in the upper part of the section of the calcareous "reefs" common in the lower portion was also noted in the outcrops of the formation at the type locality, as well as the presence of glauconite near the middle of the section and the "mottled" appearance of certain strata.

Fauna from Tapo No. 42 well.— The core samples yielded a varied fauna, including Foraminifera, mollusks, and crustaceans. The Foraminifera are shown in the accompanying check-list and will be considered in some detail. Of the mollusks, *Turritella lawsoni* Dickerson was common, occurring between the depths of 2,155 feet, 140 feet above the conglomerate, and 1,318 feet, where it is abundant. *Turritella*

CHECK-LIST OF FORAMINIFERA FROM TAPO NO. 42 WELL,

SPECIES	DEPTH OF SAMPLE AS LOGGED																													
LEGEND A—Abundant C—Common P—Present	261– 269	269– 280	280– 298	407– 425	441– 447	471– 489	489– 503	503– 521	521– 539	539– 555	555– 561	561– 571	571– 587	604– 6'0	620– 637	671– 688	688– 704	704– 715	718– 735	735– 745	745– 761	776– 791	809– 827	827– 645	863– 881
Amphimorphina californica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	P	P	P	–	–	–	–
Allomorphina cf. *macrostoma*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	P	P	–	–	–
Amphistegina californica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asterigerina simiensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asterigerina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	–
Bathysiphon cf. *eocenica*	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	–
Bulimina cf. *sculptilis*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bulimina sp.B.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	P	–	P	P	–	–
Bulimina sp.A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P
Cassidulina sp.	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chilostomella cylindroides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	P	P	–	–	P	–	–	–
Cibicides sp.	–	–	–	P	–	P	P	–	P	–	P	P	P	–	–	–	P	–	–	P	–	–	–	–	P
Cyclammina simiensis	–	–	–	–	–	–	–	C	P	A	P	C	C	P	P	P	P	–	C	P	C	P	–	–	–
Dentalina cf. *approximata*	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	P	–	–	P	–	–	–
Dentalina communis (?)	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dentalina cf. *consobrina*	–	–	–	–	–	–	P	–	–	–	P	P	P	–	–	P	–	–	–	–	P	P	P	–	–
Dentalina cf. *jacksonensis*	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	P	–	P	–	P	P	–	–	–	–
Dentalina oolinata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–
Dentalina cf. *pauperata*	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	P	–	P	P	–	–	–	–
Dictyoconus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Discocyclina cloptoni	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Discorbis sp.	C	A	–	P	P	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–
Epistomina eocenica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–
Eponides yeguaensis	P	–	P	–	P	–	–	–	P	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–
Eponides minima	–	–	–	–	–	–	P	–	–	–	–	P	–	–	–	–	–	–	–	–	–	P	–	–	–
Gyroidina orbicularis var. *obliquata*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	P	–	–	P	P	–	–	–
Gyroidina simiensis	A	A	C	–	–	–	P	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–
Gyroidina soldanii var. *octocamerata*	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	P	P	–	–	P	–	–	–
Haplophragmoides cf. *scitulum*	–	–	–	–	–	P	–	–	–	–	–	–	P	–	–	–	–	–	–	–	P	–	–	–	–
Lagena sp.	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Marginulina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Massilina decorata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–
Nodosaria sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nodosaria latejugata	–	P	P	–	–	–	–	P	P	–	–	P	–	–	P	–	–	P	–	P	–	–	–	–	–
Nonion cf. *applini*	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Operculina cushmani	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pseudoglandulina (?) sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	P	–	–	P	–	–	–	–	–
Quinqueloculina anguina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Quinqueloculina laevigata (?)	–	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Robulus articulatus (?)	–	P	P	–	P	P	P	–	P	–	P	P	P	P	P	P	–	–	–	P	P	P	P	–	–
Robulus mexicanus var. *nudicostatus*	–	P	–	–	–	–	–	–	P	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–
Robulus pseudocultratus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Robulus pseudovortex	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	P	–	–	–	–
Robulus cf. *theta*	P	P	–	–	–	–	–	–	–	–	P	P	–	–	–	–	P	–	–	–	–	–	–	–	–
Spiroplectammina sp.	–	–	–	–	–	–	–	–	–	–	P	–	–	P	–	–	P	P	–	–	–	P	–	–	–
Triloculina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Virgulina zelina	–	–	–	–	–	–	–	–	–	–	–	–	–	P	–	–	–	–	P	–	–	–	–	–	–

TAPO CANYON, VENTURA COUNTY, CALIFORNIA

DEPTH OF SAMPLE AS LOGGED

899– 912	912– 930	948– 966	1,016–1,034	1,070–1,085	1,085–1,103	1,111–1,129	1,129–1,146	1,146–1,156	1,156–1,165	1,165–1,182	1,218–1,232	1,266–1,269	1,303–1,318	1,342–1,353	1,426–1,435	1,519–1,537	1,638–1,642	1,642–1,660	1,709–1,725	1,778–1,795	1,802–1,814	1,814–1,832	1,832–1,850	1,850–1,862	1,862–1,878	1,878–1,896	1,896–1,910	1,910–1,928	1,961–1,979	1,979–1,997	1,997–2,015	2,015–2,037	2,040–2,057	2,066–2,084	2,084–2,102	2,102–2,119
P	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	A	P	P	—	P	P	—	—	—	—	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	P	—	—	—	P	—	—	—	A	—	—	—	—	A	—	P	—	—	—	—	—	—	—	C	—	—	—	—	—	—	—	—	—	—	—
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buwaldana Dickerson is present from a depth of 298 feet to 1,896 feet and *Turritella applini* M. A. Hanna is represented by specimens between the depths of 1,285 feet and 2,084 feet. The characteristic Eocene species *Ectinochilus macilentus* (White) was found at 1,146 feet and again at 1,680 feet and *Ficopsis remondii* Gabb was present at 2,140 feet.

The crustaceans, identified by Miss Mary J. Rathbun of the United States National Museum, include *Ischnodactylus* n. sp. found at 1,642 feet, *Plagiolophus weaveri* Rathbun, *Portunites insculpta* Rathbun, and *Ranincides vaderensis* Rathbun. *Plagiolophus weaveri* occurs in Tapo No. 42 at 407 feet and again at 1,802 feet, and is also recorded by Rathbun (1926, p. 36) from "near base of Tejon formation, middle Eocene," of Salt Creek, Coalinga Quadrangle; from 4 miles south of Martinez and east of the road to Walnut Creek, Contra Costa County, "upper beds, Martinez formation" ["Domengine"]; and from the middle Eocene Rose Canyon shale of the La Jolla Quadrangle, San Diego County, California. *Portunites insculpta*, found at 1,642 feet in Tapo No. 42, is recorded by Rathbun (1926, p. 71) from the "middle Eocene series" of Oregon, as is *Raninoides vaderensis*, found at 298 feet in Tapo No. 42, which is also recorded from Washington, near Vader, Lewis County, in "Upper Eocene Series, Tejon formation." Rathbun (1926, p. 2) says concerning the family *Raninidae* "worthy of note is the prevalence of members of the family beginning with the Eocene."

It is concluded that the strata encountered in Tapo No. 42 below the coarse white sandstone of the Sespe formation at 260 feet are stratigraphically, lithologically, and paleontologically the equivalent of the Llajas formation exposed in Las Llajas Canyon and that the faunal assemblages yielded by the cores are of Llajas (middle Eocene) age.

Zones.—Future study may show that the faunal change beginning at 1,050 feet in Tapo No. 42, where grains of glauconite were found, and at the top of the blue shale at 920 feet in the surface section, 55 feet above a glauconitic siltstone "reef," may be of zonal significance. Rare or absent in the upper 900 feet of the Llajas formation are such species as *Amphistegina californica*, *Asterigerina simiensis*, *Discocyclina cloptoni*, *Dictyoconus* sp. (?), *Operculina cushmani*, and *Turritella lawsoni*.

On the other hand, the following species among others occur in the upper 900 feet and are rare or absent in the lower part of the formation: *Amphimorphina californica*, *Cyclammina simiensis*, *Dentalina* cf. *jacksonensis*, *Gyroidina obliquata*, *Gyroidina simiensis*, *Gyroidina octocamerata*, *Robulus* cf. *theta*, and *Spiroplectammina* sp. (?).

The significance of the faunal differences noted can not be evaluated at this time.

DESCRIPTION OF COLLECTING LOCALITIES

The following numbers are Leland Stanford Junior University fossil localities in the Santa Susana quadrangle, Ventura County, California. Locations are indicated by measurements in inches on the U. S. Geological Survey's topographic map of the Santa Susana

quadrangle starting from Benchmark 961 at Santa Susana.

1086. Ridge on southwest side of branch canyon entering Las Llajas Canyon from the northwest, 1.65 miles up the canyon from the conglomerate ridge at its mouth; about 125 feet stratigraphically below hard bed of brown glauconitic sandstone; 2.84 inches north and 1.82 inches east of B. M. 961. Llajas formation.

1087. Same ridge as Loc. 1086, 25 feet stratigraphically below glauconitic bed. Llajas formation.

1088. On southwest end of ridge on northeast side of branch canyon of Loc. 1086, in hard brown sandstone; 2.84 inches north and 1.94 inches east of B. M. 961. Llajas formation.

1089. Fifty feet stratigraphically below Loc. 1088, on steep slope of ridge. Llajas formation.

1090 Top of conglomerate ridge at mouth of Las Llajas Canyon, south side, S. 81°E. of Marrland Country Club; 1.98 inches north and 1.22 inches east of B. M. 961. Llajas formation.

1091. Same ridge as Loc. 1090, in sandstone about 155 feet stratigraphically below base of conglomerate; 1.86 inches north and 1.34 inches east of B. M. 961. Santa Susana (?) formation.

1092. On old road up ridge on north side of mouth of Las Llajas Canyon and just east of the ridge of north-south striking conglomerate. Elev. 1550; 2.28 inches north and 1.46 inches east of B. M. 961. Llajas (?) formation.

1093. Near top of ridge just east of old well location at head of branch canyon described for Loc. 1086; 3.04 inches north and 1.66 inches east of B. M. 961. Llajas formation.

1094. Head of first large canyon west of north branch (locally known as Oil Canyon) of Las Llajas Canyon; 2.74 inches north and 0.38 inches east of B. M. 961. Llajas formation.

1095. Second large branch canyon on west side of north branch of Las Llajas Canyon; 2.66 inches north and 0.64 inches east of B. M. 961. Llajas formation.

1096. First large branch canyon on west side of north branch of Las Llajas Canyon, south of Loc. 1095 and north of Marrland Country Club; 2.52 inches north and 0.42 inches east of B. M. 961. Llajas formation.

1097. In branch canyon which enters Las Llajas Canyon from the northwest, 1.65 miles up the canyon from the conglomerate ridge at its mouth. Beds are exposed in southwest wall of canyon between Loc. 1086 and 1089. Llajas formation.

1098. Two hundred feet up branch canyon which enters Las Llajas Canyon from the east at the point where the latter swings abruptly from south to west; 2.06 inches north and 1.92 inches east of B. M. 961. Martinez formation (?).

1099. The Richfield Oil Company's Tapo No. 42 well located in Tapo Canyon, Simi Valley, sec. 36, T. 3 N., R. 18 W., San Bernardino meridian. Elev. 1129.67 feet. Total depth 2,417 feet.

1968. Ridge on north side of north branch of Las Llajas Canyon, at a point where north branch swings from north to a northeasterly direction; 2.92 inches north and 1.01 inches east of B. M. 961. Llajas formation, at contact with overlying Sespe.

1969. Ridge on north side of north branch of Las Llajas Canyon, immediately southwest of Loc. 1968 and projecting into the acute angle formed by the junction of the north branch and its first large tributary from the northwest; 2.88 inches north and 0.91 inches east of B. M. 961. Llajas formation.

1970. In east bank of north branch of Las Llajas Canyon opposite the point at which the amphitheater of Locality 1095 enters the main drainage; 2.57 inches north and 1.01 inches east of B. M. 961. Santa Susana formation.

THE FORAMINIFERAL FAUNA

On the whole, the fauna is not very well preserved, although some of the specimens wash out fairly well

and show the essential details. Numerous species are represented by very few or broken specimens, and in some the main characters must depend on specimens which are largely internal casts. However, there is a considerable number of species represented by adequately preserved specimens free from matrix.

A number of species are evidently identical with those described by Cushman and G. D. Hanna (1927) from the upper Eocene of the Coalinga region. A number of others are very close or identical with species from a somewhat lower Eocene (Cushman and M. A. Hanna, 1927). Other species appear similar to those described from the general Claiborne Eocene (Cole, 1927). Of much importance is the discovery of a species of *Dictyoconus* in this material, for this is a genus of middle Eocene age wherever it has been previously known. A number of species are represented by material of too few specimens or not sufficiently well preserved to make specific identification possible. Some of these are figured for future reference, however, with the hope that better material will eventually be found. We are indebted to Miss Patricia Edwards for her accurate drawings of the foraminifera.

SYSTEMATIC DESCRIPTIONS

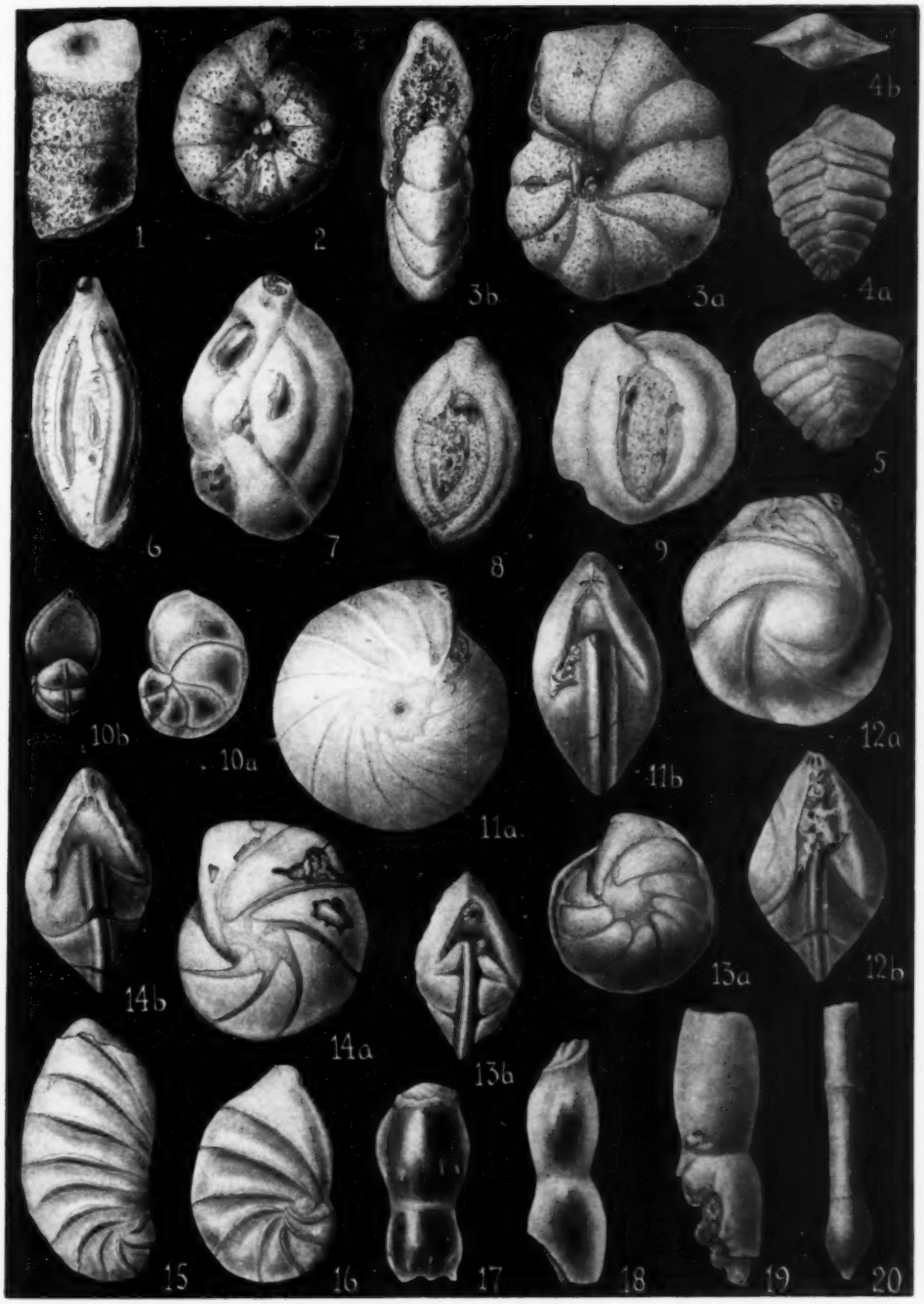
Genus BATHYSIPHON

BATHYSIPHON cf. EOCENICA
Cushman and G. D. Hanna
Plate 74, figure 1

There are numerous specimens of *Bathysiphon*, all fragmentary, which may be referred to the above species described from the upper Eocene, near Coalinga, California. Most of our specimens have a very small chamber in comparison to the thickness of the wall as may be seen from our figure, but there are other specimens that show a closer relationship to

EXPLANATION OF PLATE 74

FIGS. *1*—*Bathysiphon* cf. *eocenica* Cushman and G. D. Hanna, ×25. Tapo No. 42, 912–930 ft. (p. 508)
2—*Haplophragmoides* cf. *scitulum* (H. B. Brady), ×50. Tapo No. 42, 489–503 ft. (p. 509)
3—*Cyclammina simiensis* Cushman and McMasters, n. sp., ×22. *a*, Front view; *b*, apertural view. Tapo No. 42, 571–587 ft. (p. 509)
4, 5—*Spiroplectammina* sp., ×55. *4a*, Front view; *4b*, apertural view. Tapo No. 42, 912–930 ft. (p. 509)
6—*Quinqueloculina anguina* Terquem, ×40. L.S.J.U. Loc. 1095. (p. 509)
7—"*Quinqueloculina laevigata*" d'Orbigny (?), ×60. Tapo No. 42, 1,070–1,085 ft. (p. 509)
8—*Massilina decorata* Cushman, ×80. Tapo No. 42, 776–791 ft. (p. 510)
9—*Triloculina* sp., ×60. Tapo No. 42, 267–280 ft. (p. 510)
10—*Robulus* cf. *theta* (Cole), ×55. *a*, Side view; *b*, apertural view. Tapo No. 42, 561–571 ft. (p. 510)
11—*Robulus* sp., ×20. *a*, Side view; *b*, apertural view. L.S.J.U. Loc. 1096. (p. 510)
12—*Robulus pseudovortex* Cole, ×35. *a*, Side view; *b*, apertural view. Tapo No. 42, 471–489 ft. (p. 510)
13—*Robulus pseudocultratus* Cole, ×35. *a*, Side view; *b*, apertural view. Tapo No. 42, 1,111–1,129 ft. (p. 510)
14—*Robulus articulatus* (Reuss)(?), ×35. *a*, Side view; *b*, apertural view. L.S.J.U. Loc. 1096. (p. 511)
15, 16—*Robulus mexicanus* (Cushman), var. *nudicostatus* (Cushman and G. D. Hanna). Fig. *15*, ×35. L.S.J.U. Loc. 1097. Fig. *16*, ×28. Loc. 1096. (p. 511)
17—*Dentalina oolinata* (Cole), ×80. Tapo No. 42, 735–745 ft. (p. 512)
18–20—*Dentalina* cf. *consobrina* d'Orbigny. Fig. *18*, ×50. Tapo No. 42, 899–912 ft. Fig. *19*, ×50. Tapo No. 42, 555–561 ft. Fig. *20*, ×25. Tapo No. 42, 718–735 ft. (p. 511)



Cushman and McMasters, Eocene Foraminifera

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the larger chambered form from Coalinga.

Genus HAPLOPHRAGMOIDES

HAPLOPHRAGMOIDES cf. SCITULUM (H. B. Brady)
Plate 74, figure 2

A single specimen occurs in the collection from 489 to 503 feet in the Tapo No. 42 well which is here figured. It is partially evolute and very well preserved. The sutures are distinct, straight and radial. The test is distinctly umbilicate. The specimens strongly resemble that of Brady and in the absence of more material it is referred here. It occurs also in the well at 571 to 587 feet and 745 to 761 feet.

Genus CYCLAMMINA

CYCLAMMINA SIMIENSIS Cushman and McMasters, n. sp.
Plate 74, figures 3*a*, *b*

Test planospiral, compressed, biumbilicate, periphery rounded, often slightly lobulate; chambers about ten in the adult coil, of rather uniform size, very slightly inflated, interior labyrinthic; sutures distinct, slightly depressed, usually sigmoid; wall finely arenaceous, with much cement, surface smoothly finished; aperture multiple, represented by several rounded openings in the middle and lower portions of the apertural face. Length up to 2.50 mm.; thickness 0.60 mm. to 0.85 mm.

Holotype (Cushman Coll. No. 22594) from the Eocene, Llajas formation, from Core No 27, 571 to 587 feet, Richfield Oil Co., Tapo No. 42, Simi field, Ventura County, California. Specimens also occur in surface samples from Santa Susana Quadrangle, L.S.J.U. Loc. 1097, but are not as well preserved as are those from the cores.

The species resembles *Cyclammina cancellata* H. B. Brady, but is much more compressed and the periphery much less broadly rounded.

Genus SPIROPLECTAMMINA

SPIROPLECTAMMINA sp.
Plate 74, figures 4, 5

There are a very few specimens of a form very close to *S. mississippiensis* (Cushman) but with lower chambers and the sutures usually clear, without any incrustations, but some specimens do show this in some degree. In some respects, it also resembles var. *alabamensis* (Cushman) but the chambers are not as high and the sutures straighter.

Genus DICTYOCONUS

DICTYOCONUS sp.
Plate 75, figure 17

A single specimen evidently belonging to this genus occurred in the material from Tapo No. 42, at a depth of 1,070 to 1,085 feet. The genus is apparently limited to the middle Eocene and is, therefore, an excellent fossil to determine the age of this portion of the Las Llajas formation. More material is necessary for a specific determination.

Genus QUINQUELOCULINA

QUINQUELOCULINA ANGUINA Terquem
Plate 74, figure 6

In the surface sample from the Llajas formation, L.S.J.U., Loc. 1095, 500 feet below the top of the section, Santa Susana Quadrangle, there are a few specimens which very closely resemble this species (see Cushman, 1935, p. 12, pl. 2, figs. 18, 19). The specimens are represented largely by internal casts but the elongated neck and generally rounded appearance of the chambers is apparent.

"QUINQUELOCULINA LAEVIGATA" d'Orbigny(?)
Plate 74, figure 7

This species occurs in the upper Eocene, Jackson formation, of the Eastern Gulf Coastal Plain and is described and figured by Cushman (1935, p. 11, pl. 2, figs. 13–15). Very similar specimens, although usually not very well preserved, occur in the well samples and from surface collections in the Llajas formation. According to the rules, d'Orbigny's name cannot be used as the species was not figured by him until after Deshayes had also used the name for a different form accompanied by a figure. The Cali-

fornia specimens closely resemble those of the Gulf Coastal Plain, but material is very meager indeed.

Genus MASSILINA

MASSILINA DECORATA Cushman

Plate 74, figure 8

Massilina decorata CUSHMAN, *1922*, U. S. Geol. Survey, Prof. Paper 129-F, p. 143, pl. 34, fig. 7.

There are specimens close to this species that occur very rarely in our material. One of these is here figured. The surface is rather smooth and polished, although finely pitted.

Genus TRILOCULINA

TRILOCULINA sp.

Plate 74, figure 9

Very rare and imperfect specimens apparently triloculine are found in the Tapo No. 42 well. Without more and better preserved specimens it seems unwise to try to give these a specific name.

Genus ROBULUS

ROBULUS cf. THETA (Cole)

Plate 74, figures 10*a*, *b*

The single figured specimen is from the Tapo No. 42 well at a depth of 561 to 571 feet. It is evidently a young specimen and closely resembles the earliest stages in the suite of specimens of this species named by Cole. His specimens were from the Eocene, Guayabal formation of Mexico (Cole, 1927, pl. 1, fig. 17).

ROBULUS sp.

Plate 74, figures 11*a*, *b*

The large specimen figured here has many chambers but there are not enough specimens to place this definitely. It is figured here for future reference.

ROBULUS PSEUDOVORTEX Cole

Plate 74, figures 12*a*, *b*

Robulus pseudovortex COLE, *1927*, Bull. Am. Paleontology, vol. 14, no. 51, p. 19, pl. 1, fig. 12.

Our figured specimen is very similar to the type figure of this species from the Guayabal formation of Mexico. There are enough specimens to confirm the identification of this species after comparison with specimens identified by Cole.

ROBULUS PSEUDOCULTRATUS Cole

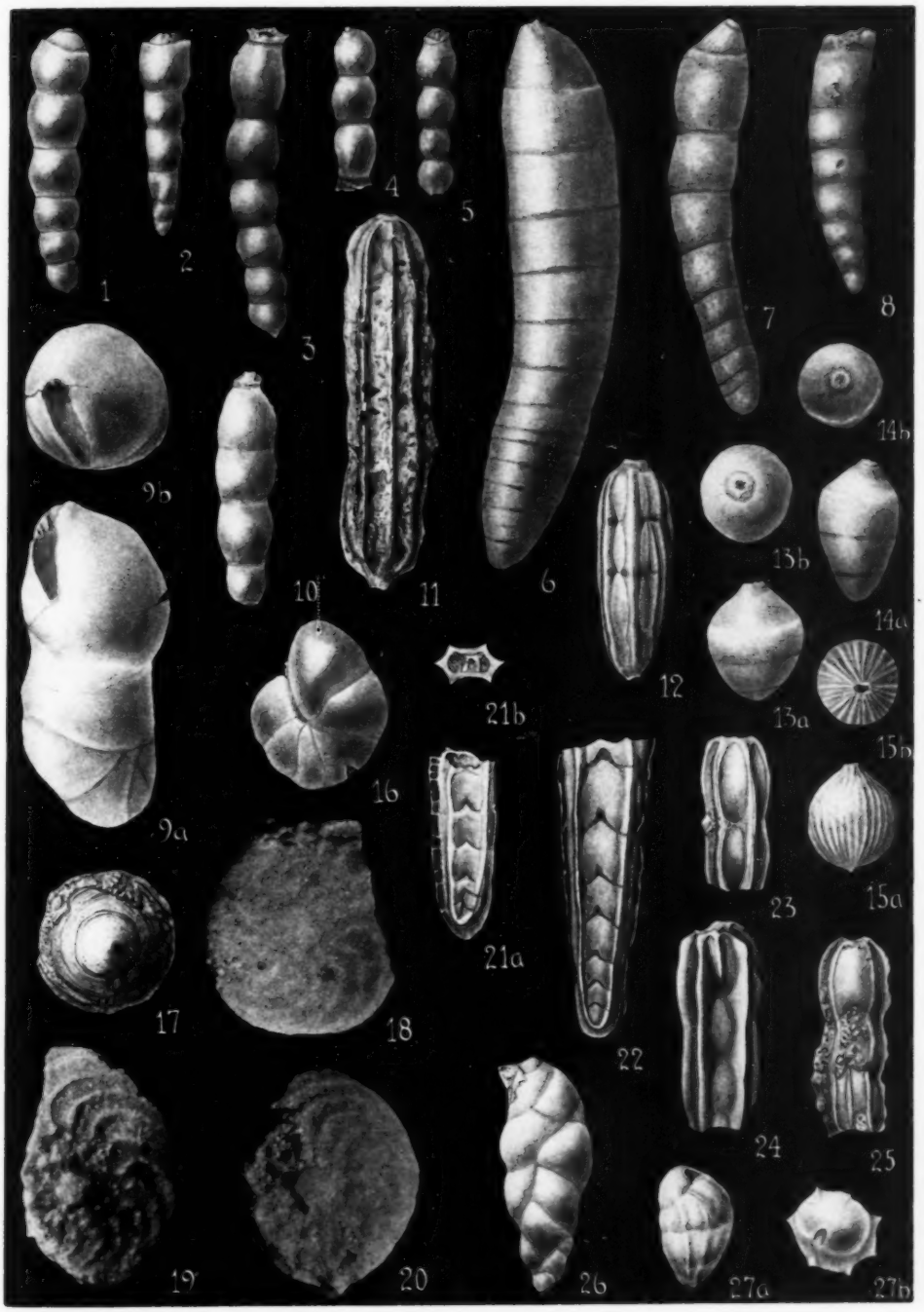
Plate 74, figures 13*a*, *b*

Robulus pseudocultratus COLE, *1927*, Bull. Am, Paleontology, vol. 14, no. 51, p. 19, pl. 1. fig. 5.

Cole's type figure shows the chambers of the last whorl all completely involute, but a series of specimens from him show

EXPLANATION OF PLATE 75

FIGS. *1, 2—Dentalina* cf. *pauperata* d'Orbigny, ×50, Tapo No. 42, 1,070–1,085 ft. (p. 511)
3–5—Dentalina jacksonensis (Cushman and Applin), ×50. Tapo No. 42, 912–930 ft. (p. 511)
6—Dentalina communis d'Orbigny (?), ×50. Tapo No. 42, 1,070–1,085 ft. (p. 511)
7, 8—Dentalina cf. *approximata* Reuss, ×50. Tapo No. 42, 1,070–1,085 ft. (p. 512)
9—Marginulina sp., ×50. *a*, Side view; *b*, apertural view. Tapo No. 42, 1,085–1,103 ft. (p. 511)
10—Nodosaria sp., ×50. Tapo No. 42, 912–930 ft. (p. 512)
11, 12—Nodosaria latejugata Gümbel, ×20. Tapo No. 42, 1,070–1,085 ft. (p. 512)
13, 14—Pseudoglandulina (?) sp., ×50. *aa*, Front views; *bb*, apertural views. Tapo No. 42. Fig. *13*. 555–561 ft. Fig. *14*, 1,070–1,085 ft. (p. 512)
15—Lagena sp., ×80. *a*, Front view; *b*, apertural view. Tapo No. 42, 555–561 ft. (p. 512)
16—Nonion cf. *applini* Howe and Wallace, ×80. Tapo No. 42, 561–571 ft. (p. 513)
17—Dictyoconus sp., ×25. Tapo No. 42, 1,070–1,085 ft. (p. 509)
18–20—Operculina cushmani Cole. Figs. *18*, *20*, ×25. Fig. *19*, ×20. L.S.J.U. Loc. 1095. (p. 513)
21–25—Amphimorphina californica Cushman and McMasters, n. sp. *21*, Early stages microspheric form, ×50. *22*, Holotype, ×50. *23–25*, Portions toward apertual end, ×35. Tapo No. 42, 718–735 ft. (p. 513)
26—Virgulina zetina Cole, ×80. Tapo No. 42, 1,165–1,185 ft. (p. 513)
27—Bulimina cf. *sculptilis* Cushman, ×50. *a*, Front view; *b*, apertural view. Tapo No. 42, 899–912 ft. (p. 513)



Cushman and McMasters, Eocene Foraminifera

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all of them with the chambers of the final whorl failing to meet at the center and a clear space in the umbilical region. Our specimens agree very closely indeed with his, and there are numerous specimens available. It is another species linking the Las Llajas material with the Guayabal.

ROBULUS ARTICULATUS (Reuss) (?)
Plate 74, figures 14*a*, *b*

Specimens similar to that figured are fairly common in the material from both well samples and surface outcrops. They are similar to the American forms that have been assigned to Reuss' species, probably incorrectly. More and better specimens are desirable to fully settle upon a name for this species.

ROBULUS MEXICANUS (Cushman) var. NUDICOSTATUS (Cushman and G. D. Hanna)
Plate 74, figures 15, 16

Cristellaria mexicana nudicosta CUSHMAN and G. D. HANNA, *1927*, California Acad. Sci., Proc., ser. 4, vol. 16, p. 216, pl. 14, fig. 2.

This variety was described from the Eocene of Coalinga. The specimens tend to become uncoiled and elongate. From the appearance of these adult uncoiled forms, it may be that *Marginulina* should be used for this form.

Genus MARGINULINA

MARGINULINA sp.
Plate 75, figures 9*a*, *b*

A single specimen, here figured, occurred in the Tapo No. 42 well at a depth of 1,085 to 1,103 feet. It is somewhat imperfect, but seems closely allied to *M. subbullata* Hantken already recorded from the upper Eocene of the Coalinga region.

Genus DENTALINA

DENTALINA cf. CONSOBRINA d'Orbigny
Plate 74, figures 18–20

Fragments somewhat similar to chambers of specimens referred to this species from the upper Eocene of Coalinga were found in our material. Definite identification must await the finding of better material. The one specimen with three chambers is very similar to the one figured from Coalinga. With these are other fragments representing single chambers which are very long and cylindrical, slightly tapering at the ends. Some of these are similar to the elongate chamber figured from Coalinga as "*Nodosaria arundinea* Schwager." They may represent adult chambers of the form here figured.

DENTALINA cf. PAUPERATA d'Orbigny
Plate 75, figures 1, 2

Two somewhat fragmentary specimens are here figured. They remotely resemble the early stages of *D. jacksonensis* (Cushman and Applin), but no complete specimens were found to make any identification more certain. They are not as curved as the more typical form which we have also figured.

DENTALINA JACKSONENSIS (Cushman and Applin)
Plate 75, figures 3–5

Nodosaria jacksonensis CUSHMAN and APPLIN, *1926*, Am. Assoc. Petroleum Geologists, Bull., vol. 10, p. 170, pl. 7, figs. 14–16.—CUSHMAN, *1927*, Jour. Paleontology, vol. 1, p. 153, pl. 24, fig. 3.—COLE, *1928*, Bull. Am. Paleontology, vol. 14, no. 53, p. 208, pl. 3, fig. 12.
Dentalina jacksonensis CUSHMAN, *1935*, U. S. Geol. Survey, Prof. Paper 181, p. 20, pl. 8, figs. 7–9.

The fragmentary specimens have the basal spine and the characteristically shaped chambers of this species, becoming more elongate in the adult.

DENTALINA COMMUNIS d'Orbigny (?)
Plate 75, figure 6

The figured specimen is somewhat questionably referred to d'Orbigny' species. It has already been recorded from the upper Eocene of Coalinga. Specimens are very rare at a depth of 1,070 to 1,085 feet in the Tapo No. 42 well. There is also a resemblance to *Dentalina cooperensis* Cushman, from the Eocene of South Carolina. Dentalinas are very variable indeed and no identification from a single specimen is worth much.

DENTALINA cf. APPROXIMATA Reuss
Plate 75, figures, 7, 8

The two specimens figured somewhat closely resemble this species of Reuss but the material is not sufficient for accurate identification.

DENTALINA OOLINATA (Cole)
Plate 74, figure 17

Nodosaria oolinata COLE, *1927*, Bull. Am. Paleontology, vol. 14, no. 51, p. 16, pl. 3, fig. 16.

The two-chambered fragment is the only one in our material, but is figured here as showing another element in common between this fauna and that of the Guayabal Eocene of Mexico. It is probably the same as the form referred to from Coalinga as "*Dentalina adolphina* d'Orbigny" (Cushman and G. D. Hanna, 1927, p. 213, pl. 13, figs. 8, 9).

Genus NODOSARIA

NODOSARIA LATEJUGATA Gümbel
Plate 75, figures 11, 12

This species has already been recorded from Coalinga and both microspheric and megalospheric specimens figured. The material from the upper part of our section seems to be identical with that from Coalinga in both microspheric and megalospheric specimens.

NODOSARIA sp.
Plate 75, figure 10

The single incomplete specimen figured seems to be different from any of the others noted here. No name is assigned to it even provisionally as it is evidently not an adult specimen but is figured for future reference as an element of the fauna from this locality.

Genus PSEUDOGLANDULINA

PSEUDOGLANDULINA (?) sp.
Plate 75, figures 13, 14

A very few small specimens evidently belong to this genus but are not adults and cannot be specifically determined.

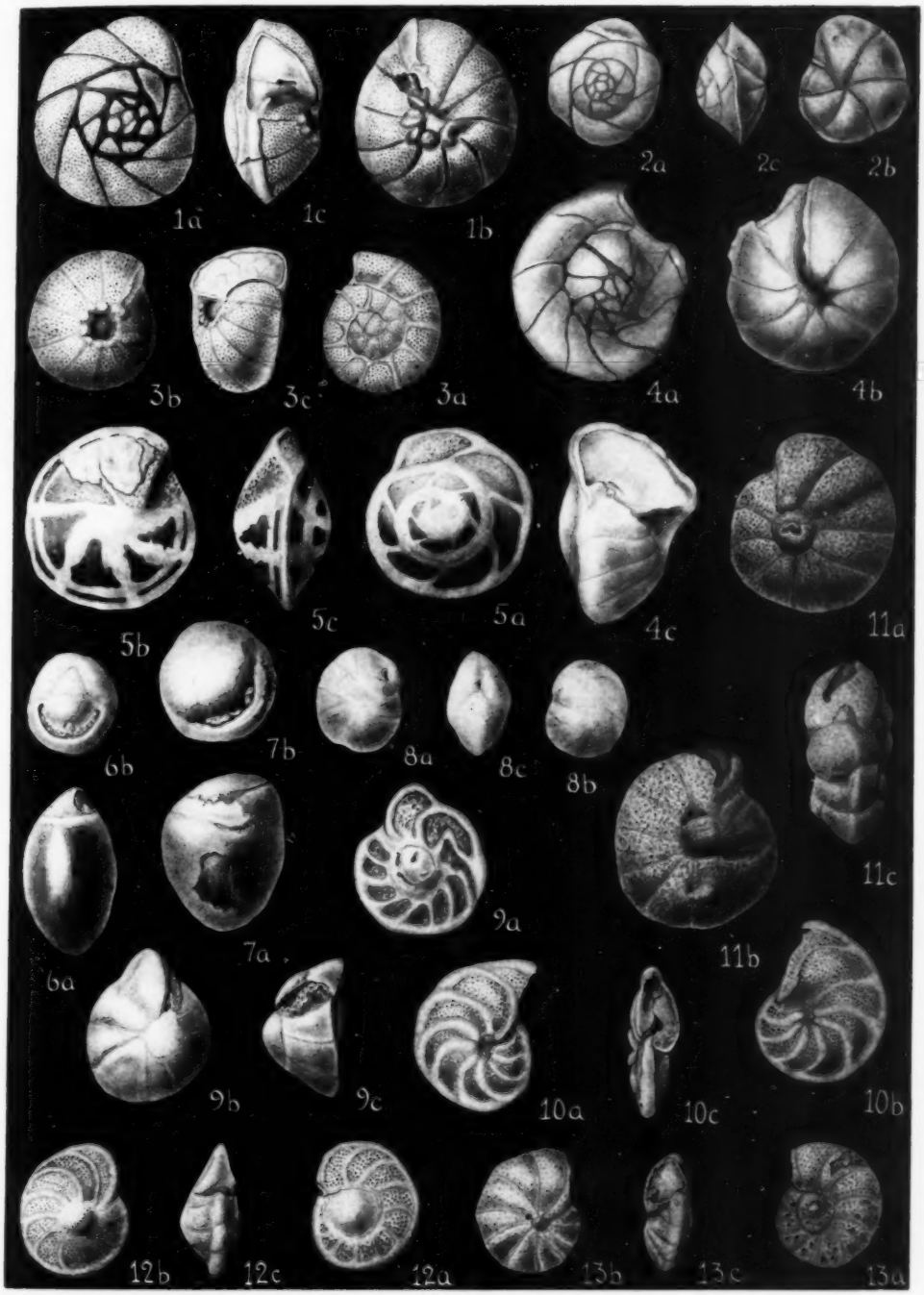
Genus LAGENA

LAGENA sp.
Plate 75, figures 15*a*, *b*

A small costate form is here figured for record. It is not specifically identified

EXPLANATION OF PLATE 76

FIGS. *1*—*Eponides yeguaensis* Weinzierl and Applin, ×35. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 280–298 ft. (p. 514)
2—*Eponides minima* Cushman, ×50. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 1,111–1,129 ft. (p. 514)
3—*Gyroidina simiensis* Cushman and McMasters, n. sp., ×60. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 267–280 ft. (p. 514)
4—*Gyroidina orbicularis* d'Orbigny var. *obliquata* Cushman and McMasters, n. var., ×60. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 620–637 ft. (p. 514)
5—*Epistomina eocenica* Cushman and M. A. Hanna, ×35. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 1,085–1,103 ft. (p. 515)
6—*Chilostomella cylindroides* Reuss, ×60. *a*, Front view, *b*, apertural view. Tapo No. 42, 718–735 ft. (p. 515)
7—*Allomorphina* cf. *macrostoma* Karrer, ×50. *a*, Front view; *b*, apertural view Tapo No. 42, 718–735 ft. (p. 516)
8—*Cassidulina* sp., ×55. *a*, *b*, Opposite sides; *c*, apertural view. Tapo No. 42, 1,111–1,129 ft. (p. 516)
9—*Cibicides* sp.A, ×55. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 1,111–1,129 ft. (p. 516)
10—*Cibicides* sp. B, ×55. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 912–930 ft. (p. 516)
11—*Anomalina* (?) sp., ×35. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 1,085–1,103 ft. (p. 516)
12—*Cibicides* sp. C, ×55. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 620–637 ft. (p. 516)
13—*Cibicides* sp. D, ×55. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Tapo No. 42, 489–503 ft. (p. 516)



Cushman and McMasters, Eocene Foraminifera

as more material would be necessary. Another very small smooth, rounded specimen has occurred but it is not well enough preserved to be sure whether it is a *Lagena* or an end chamber of a *Dentalina*.

Genus NONION

NONION cf. APPLINI Howe and Wallace
Plate 75, figure 16

A single specimen here figured from the upper part of the section resembles the species described by Howe and Wallace from the upper Eocene of Louisiana.

Genus OPERCULINA

OPERCULINA CUSHMANI Cole
Plate 75, figures 18–20; Plate 77, figure 5

Operculina cushmani COLE, *1927*, Bull. Am. Paleontology, vol. 14, no. 51, p. 23, pl. 2, fig. 13.

There are numerous specimens of a small, compressed species which seem to be identical with the species described by Cole from the Eocene, Guayabal formation of Mexico. The number of chambers is essentially the same, the sutures are raised and become beaded toward the slightly raised umbo.

Genus AMPHIMORPHINA

AMPHIMORPHINA CALIFORNICA
Cushman and McMasters, n. sp.
Plate 75, figures 21–25

Test elongate, early portion compressed, periphery sharply keeled, with supplementary keels at either side running the entire length of the test; chambers of the earliest stage in the microspheric form biserial, quickly becoming uniserial, in the megalospheric form uniserial throughout, gradually increasing in height as added, in the adult inflated and rounded in section with occasional supplementary costae in the middle; sutures distinct, slightly limbate in the compressed portion; wall smooth except for the costae; aperture rounded or elliptical, terminal. Length 1.50 mm. or more; diameter 0.30–0.35 mm.

Holotype (Cushman Coll. No. 22602) from the Eocene, Las Llajas formation, Richfield Oil Co., Tapo No. 42, 718–735 feet, Simi Valley, Ventura County, California.

In some respects this resembles the form from the Claiborne Eocene of Texas described as *Plectofrondicularia mexicana* Cushman, var. *plummerae* Weinzierl and Applin (1929, p. 401, pl. 44, fig. 3). A comparison of our species with the Texas types shows that ours is a much larger and coarser species but the two have a strong resemblance. It is also similar to species from the Eocene recently described by Cushman and Bermudez (1936).

No complete specimens were obtained but enough material is available to show the characters of both the microspheric and megalospheric forms.

Genus VIRGULINA

VIRGULINA ZETINA Cole
Plate 75, figure 26

Virgulina zetina COLE, *1927*, Bull. Am. Paleontology, vol. 14, no. 51, p. 25, pl. 5, fig. 14 (as *V. mexicana* Cole, corrected to *V. zetina* Cole).

The single specimen is identical with specimens from Cole's original material although, unfortunately, his type figure does not really show accurately the details of this species. It is another species connecting the faunas of these two regions.

Genus BULIMINA

BULIMINA cf. SCULPTILIS Cushman
Plate 75, figures 27*a*, *b*

There is a single specimen here figured that has a strong resemblance to this lower Oligocene species, but not enough specimens are available to give the full characters. It belongs to the general *B. jacksonensis-B. sculptilis* group but the costae are lower than typical.

BULIMINA sp. A.

There is a single specimen from Tapo No. 42 at a depth of 863 to 881 feet that has basal spines on the chambers and is of the general type usually referred to

Bulimina inflata Seguenza. Cole has referred a somewhat similar specimen from the Guayabal formation of Mexico to Seguenza's species with some question.

BULIMINA sp. B.

There are a few smooth Buliminas that are not well preserved and cannot be positively identified until more work has been done on these smooth forms from the Eocene.

Genus DISCORBIS

DISCORBIS sp.

There are a very few specimens, none completely preserved which may be referred to this genus. The species is keeled and has only four or five chambers in the adult whorl with very distinct perforations. The material is insufficient to warrant a specific determination.

Genus EPONIDES

EPONIDES YEGUAENSIS Weinzierl and Applin

Plate 76, figures 1*a–c*

Eponides guayabalensis Cole, var. *yeguaensis* WEINZIERL and APPLIN, *1929*, Jour. Paleontology, vol. 3, p. 406, pl. 42. figs. 2*a–c*.—CUSHMAN and DUSENBURY, *1934*, Cushman Lab. Foram. Research, Contr., vol. 10, p. 62, pl. 9, figs. 1*a–c*.

Our figured specimen is very close to the form described from the Eocene, Yegua formation, of Texas and later recorded from the Eocene, Poway conglomerate, of California. It seems to be a distinct species rather than a variety of *E. guayabalensis*. Our specimens were compared with the type.

EPONIDES MINIMA Cushman

Plate 76, figures 2*a–c*

Eponides minima CUSHMAN, *1933*, Cushman Lab. Foram. Research, Contr., vol. 9, p. 17, pl. 2, figs. 8*a–c*.

The specimen figured is from the Llajas formation of Tapo No. 42 at a depth of 1,111 to 1,129 feet. It closely resembles this species described from the upper Eocene, Cooper marl, of South Carolina. It is of very small size, with about six chambers in the adult whorl. The species also suggests *Eponides ouachitaensis* Howe and Wallace, from the upper Eocene of Louisiana.

Genus GYROIDINA

GYROIDINA SOLDANII d'Orbigny var. OCTOCAMERATA Cushman and G. D. Hanna

This variety was originally described from the Eocene of Coalinga, California, and has since been found to be widely distributed in the upper Eocene. It occurs in the Las Llajas material.

GYROIDINA ORBICULARIS d'Orbigny var. OBLIQUATA Cushman and McMasters, n. var.

Plate 76, figures 4*a–c*

Variety differing from the typical in the flattened dorsal side, very convex ventral side and very strongly oblique sutures which are often slightly sigmoid.

Holotype (Cushman Coll. No. 22603) from Eocene, Las Llajas formation, Richfield Oil Co., Tapo No. 42, 620 to 637 feet, Simi Valley, Ventura County, California.

GYROIDINA SIMIENSIS Cushman and McMasters, n. sp.

Plate 76, figures 3*a–c*

Test plano-convex, dorsal side flattened, ventral side very convex, strongly

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EXPLANATION OF PLATE 77

FIGS. *1–4*—*Asterigerina simiensis* Cushman and McMasters, n. sp., ×32. Fig. *3*, holotype. *1*, *2*, *4*, Paratypes. Fig. *1*, Dorsal view; figs. *2–4*, ventral views. Figs. *1*, *4*, L.S.J.U. Loc. 1096. Figs. *2*, *3*, Loc. 1097. (p. 515)

5—*Operculina cushmani* Cole, ×32. L.S.J.U. Loc. 1097. (p. 513)

6–9—*Discocyclina doptoni* Vaughan. Figs. *6–8*, Exteriors, ×36. Fig. *9*, Median section. ×30. Fig. *9*. Tapo No. 42, 1,814–1,832 ft. Figs. *6–8*. L.S.J.U. Loc. 1095. (p. 516)

Cushman and McMasters, Eocene Foraminifera

umbilicate, periphery very broadly rounded; chambers distinct, ten or more in the last-formed whorl in the adult, of rather uniform shape, increasing very gradually in size as added, very slightly inflated; sutures distinct, strongly limbate, on the dorsal side thickened and slightly raised, ventrally flush with the surface, each ending at the umbilicus in a thickened knob; wall distinctly perforate; aperture a narrow, elongate slit on the ventral side between the periphery and umbilicus. Diameter 0.40 mm.–0.50 mm.; height 0.25 mm.–0.30 mm.

Holotype (Cushman Coll. No. 22604) from Eocene, Las Llajas formation, Richfield Oil Co., Tapo No. 42, 267 to 280 feet, Simi Valley, Ventura County, California.

This species is fairly common and should make an excellent marker for this part of the formation. It has a much more rounded periphery than either *G. soldanii* or *G. orbicularis*.

Genus EPISTOMINA

EPISTOMINA EOCENICA Cushman and M. A. Hanna

Plate 76, figures 5*a–c*

Epistomina eocenica CUSHMAN and M. A. HANNA, *1927*, San Diego Soc. Nat. Hist., Trans., vol. 5, p. 53, pl. 5, figs. 4, 5.

This species originally described from the Eocene near La Jolla, California, occurs well preserved in the Llajas material. It has very broad limbate sutures and six or seven chambers in the final whorl. The species is known from both the Jackson and Claiborne Eocene.

Genus ASTERIGERINA

ASTERIGERINA SIMIENSIS Cushman and McMasters, n. sp.

Plate 77, figures 1–4

Test trochoid, biconvex, periphery subacute; chambers twelve to fifteen in the final whorl, of generally uniform size, on the ventral side with a series of rhomboid, supplementary chambers alternating with the regular series and covering their inner portions; sutures on the dorsal side ornamented with a line of rounded or elliptical knobs, less prominent on the ventral side; wall distinctly perforate. Diameter up to 1.00 mm.; thickness 0.35–0.40 mm.

Holotype (Cushman Coll. No. 22605) from L.S.J.U. Loc. 1097, 1088 feet below top of section, Santa Susana Quadrangle, California, in branch canyon which enters Las Llajas canyon f om the northwest, 1.65 miles up the canyon from the conglomerate ridge at its mouth.

This is one of the striking species of this material and should prove to be a definite marker for this part of the section. Its beaded sutures and many chambers will distinguish it from other species.

ASTERIGERINA sp.

There is a single well-preserved specimen of a very small *Asterigerina* which has a flattened dorsal side and very convex ventral one, the periphery sharply angled, almost keeled, with about nine chambers in the final whorl, the sutures very oblique. This specimen is from Tapo No. 42 at a depth of 1,342 to 1,353 feet.

Genus AMPHISTEGINA

AMPHISTEGINA CALIFORNICA Cushman and M. A. Hanna

Amphistegina californica CUSHMAN and M. A. HANNA, *1927*, San Diego Soc. Nat. Hist., Trans., vol. 5, p. 56, pl. 6, figs. 3–5.

Specimens from the Llajas formation of Tapo No. 42 at a depth of 1,070 to 1,085 feet are apparently identical with the species described from the Eocene near San Diego in the above reference.

Genus CHILOSTOMELLA

CHILOSTOMELLA CYLINDROIDES Reuss

Plate 76, figures 6*a*, *b*

Rare specimens occurring with the *Allomorphina* noted below are close to Reuss' species described from the Oligocene of Germany. It has been recorded from the Jackson Eocene of Louisiana by Howe and Wallace (1932, p. 72, pl. 14, figs. 1*a*, *b*).

Genus ALLOMORPHINA

ALLOMORPHINA cf. MACROSTOMA Karrer

Plate 76, figures 7*a*, *b*

In the material from Tapo No. 42 at a depth of 718 to 735 feet, there are several specimens of an *Allomorphina* that is tentatively referred to Karrer's species. It is similar to that recorded by Nuttall (1935, p. 129, pl. 15, fig. 28) from the Eocene of Trinidad. The material is filled with pyrite and none of the specimens is perfectly preserved.

Genus CASSIDULINA

CASSIDULINA sp.

Plate 76, figures 8*a–c*

A very small species of *Cassidulina* occurs in Tapo No. 42 at a depth of 1,111 to 1,129 feet. None of the specimens shows the sutures clearly. It is more compressed than the common Eocene *C. globosa* of Hantken, but more and better material is needed for an adequate description.

Genus ANOMALINA

ANOMALINA (?) sp.

Plate 76, figures 11*a–c*

The peculiar form figured is not sufficiently well preserved for specific identification. It is apparently a species of *Anomalina*. It somewhat resembles "*Cibicides sassei* Cole" from the Guayabal formation of Mexico.

CIBICIDES sp. A.

Plate 76, figures 9*a–c*

The figured specimen shows a peculiar form which may not be an adult and needs further material. The ventral side is very strongly convex and umbonate, the dorsal side has raised sutures and a coarsely perforats wall between.

CIBICIDES sp. B.

Plate 76, figures 10*a–c*

Thi peculiar pecimen has the chambers nearly involute on the two sides but the test unequally biconvex. The sutures are very strongly limbate and raised, while the wall is coarsely perforate.

CIBICIDES sp. C.

Plate 76, figures 12*a–c*

This may possibly be a young stage of *Cibicides coalingensis* (Cushman and G. D. Hanna). The test is umbonate on both sides but is unequally biconvex.

CIBICIDES sp. D.

Plate 76, figures 13*a–c*

This specimen is not as well preserved as the other figured ones but evidently represents an entirely different species.

Genus DISCOCYCLINA

DISCOCYCLINA CLOPTONI Vaughan

Plate 77, figures 6–9

Discocyclina cloptoni VAUGHAN, *1929*, U. S. Nat. Mus., Proc., vol. 76, Art. 3, pp. 14, 15, pl. 5, figs. 1–6.

The types of this species are from the Tepetate formation, "middle or upper Eocene" of Lower California. Specimens identified as this species occur in the Las Llajas formation at localities 1093 and 1095 about 920 to 975 feet stratigraphically below the Sespe formation. The surface of these thin specimens is not distinctly papillate, as in *D. clarki*, embryonic apparatus is composed of two or more chambers, and the species is not umbonate. The Llajas specimens are generally from 5 to 7± mm. in diameter, which fact aids in distinguishing them from *Discocyclina psila* Woodring.

The above notes on this species were furnished by Dr. H. G. Schenck.

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J. A. CUSHMAN, SHARON, MASS. J. H. MCMASTERS, BAKERSFIELD, CALIF. MANUSCRIPT RECEIVED BY THE EDITOR, APRIL, 1936.

JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 6, PP. 518–519, TEXT-FIGS. 1–7,
SEPTEMBER, 1936

A FOSSILIFEROUS HORIZON FROM THE LOWER PERMIAN OF CADDO COUNTY, OKLAHOMA

R. W. HARRIS and FRANK WORRELL

In an examination of cuttings from wells from Cement field of Oklahoma, the authors discovered a fossiliferous arenaceous limestone zone characterized by two new species of Ostracoda of the genera *Paraparchites* and *Bythocypris*. The zone is about 30 feet thick; occurs approximately 400 feet above the base of the Permian as here defined, and is apparently persistent in the field. We noted it in Cobza Simms-Wrightman No. 1, at 2,670 feet, and in the Mid-Kansas Gregory No. 1, sec. 31, T. 6 N., R. 9 W., at 2,490 feet. The bythocyproid species was definitely identified in the latter well only. The *Paraparchites* zone has been recorded by the junior writer from various wells in the field, namely: Magnolia Petroleum Stella Lacky No. 3, sec. 11, T. 5 N., R. 9 W., at 2,475 feet; Mid-Kansas Gregory No. 2, sec. 31, T. 6 N., R. 9 W., at 2,565 feet; and Mid-Kansas Culp No. 6, sec. 6, T. 5 N., R. 5 W., at 2,460 feet.

The species are described and illustrated as follows.

PARAPARCHITES PUNCTATUS Harris and Worrell, n. sp.

Text-figures 1, 1*a*, 1*b*, 1*c*, 2, 3

Carapace subquadrate in side view, subequilaterally symmetrical, posterior end faintly produced and slightly higher; hinge-line straight, channeled, ventral margin faintly rounded, subparallel to hinge line, cardinal angles rounded, anterior the more abrupt; a narrow internal peripheral flange borders the free margins; surface evenly and flatly biconvex, thickest along median line, characterized by innumerable fine punctae with indefinite distribution, sometimes devoid of punctae along periphery. Length 1.6 mm., height 1 mm.

Holotype, No. PerW 10701, Univ. Okla., from arenaceous limestone in Simms-Wrightman Cobza No. 1 well, sec. 24, T. 6 N., R. 11 W., at 2,670 feet, Cement field, Caddo County, Oklahoma. Permian.

Remarks.—Numerous molts representing all stages of growth are common. The smaller molts are thicker, steeply biconvex, and exhibit a more pronounced backward swing.

This species differs from *P. ornatus* Delo in its more quadrate outline and more numerous and finer punctae; it lacks the dorsal arching of that species. The new species resembles *Amphissites simplicissimus* Knight in shape and ornamentation, but lacks the median pit of that form.

BYTHOCYPRIS ERECTUS Harris and Worrell, n. sp.

Text-figures 4, 4*a*, 4*b*, 5–7

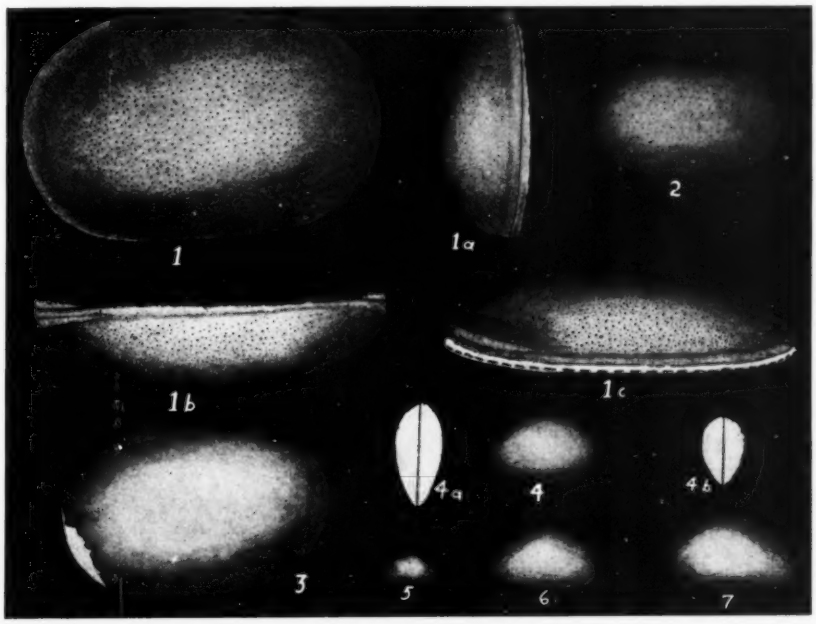
Small, simple, inflated, ovate, seed-like form without distinct marginal angles; dorsal margin somewhat highly and evenly arched, highest centrally, ventral margin flat, anterior end broadly and evenly rounded, posterior nose more sharply rounded and slightly lower; overlap of left valve indistinct dorsally, prominent ventrally, especially at central region. Length 0.6 mm., height 0.4 mm.

Holotype, No. PerW 10702, Univ. Okla., from arenaceous limestone in Simms-Wrightman Cobza No. 1, sec. 24, T. 6 N., R. 11 W., at 2,680 feet, Cement field, Caddo County, Oklahoma. Permian.

Remarks.—This species is an unusually tall representative of the genus. Earlier molts are more triangular in outline than mature forms.

R. W. HARRIS, UNIVERSITY OF OKLAHOMA, NORMAN, OKLA.
FRANK WORRELL, UNIVERSITY OF OKLAHOMA, NORMAN, OKLA.

MANUSCRIPT RECEIVED BY THE EDITOR, FEBRUARY 5, 1936.



FIGS. *1–1c, 2, 3—Paraparchites punctatus* Harris and Worrell, n. sp. Right valves. *1*, Lateral view of adult; *1a*, anterior; *1b*, dorsal; *1c*, ventral. *2*, Earlier molt. *3*, Exfoliated carapace. ×30.

4–4b, 5–7—Bythocypris erectus Harris and Worrell, n. sp. *4*, *4a*, *4b*, Lateral, dorsal, and anterior views of right valve. *5*, Early molt left valve. *6*, Intermediate molt left valve. *7*, Adult left valve. ×30.

JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 6, PP. 520–534, SEPTEMBER, 1936

NOTES ON PALEOZOIC GASTROPODA

J. BROOKES KNIGHT

ABSTRACT

The purpose of this paper is to make a number of taxonomic changes and nomenclatural corrections in previous papers by the author on Carboniferous gastropods.

Cyclozyga mirabilis Knight, 1930 is designated genotype of *Cyclozyga* Knight, 1930. It is shown that *Buccinum acutum* Sowerby, 1827, and not *Buccininites arculatum* Schlotheim, 1820, is genotype of *Macrochilina* Bayle, 1880, and that *Buccinum acutum* is closely congeneric with *Soleniscus typicus* Meek and Worthen. *Macrochilina* thus becomes a close subjective synonym of *Soleniscus* and the name *Strobeus* deKoninck is properly applied to those species hitherto referred to *Macrochilina*. It is shown that *Strophostylus andrewsi* Hall, 1860, and not *S. elegans* Hall, 1860, is genotype of *Strophostylus* Hall, 1859. *Helictostylus* Knight, 1934, is thus n exact synonym of *Strophostylus* Hall. Emendations of the orthography of several generic and specific names is discussed. It is held that *Platyostoma* Conrad, 1842, is invalidly emended to *Platystoma*, and hence is not an homonym of several prior usages of *Platystoma*, and that *Diaphorostoma* Fischer, 1887, must, therefore, be suppressed as a subsequent exact synonym of *Platyostoma*, a prior valid name.

New names proposed are: *Flemingella* for *Flemingia* deKoninck, 1881 (not Johnston, 1845); *Rhaphischisma* for *Rotellina* deKoninck, 1881 (not Agassiz, 1846).

New genera proposed are: *Leptoptygma* Knight (genotype *Auriptygma virgatum* Knight, 1931); *Girtyspira* Knight (genotype *Bulimella canaliculata* Hall, 1858); and *Colpites* Girty mss.. Knight (genotype *Naticopsis monilifera* White, 1880).

A year of work in the museums of Europe[1] has given me an opportunity to learn much of the true characters of the genotype species of many gastropod genera from a study of the type specimens themselves, whereas before I had known them inadequately from the literature. In connection with that work, I have also had occasion to go more deeply into nomenclatural technicalities in respect to all of such genera. As a result, there are a number of changes and corrections that should be made in my previous papers on Pennsylvanian gastropods and it seems proper that they be made at the earliest opportunity lest the errors be overlooked and become more deeply imbedded in the literature. I shall take up in the order of publication in my papers each generic or specific name that appears to be in need of change or correction on the above grounds and shall also recapitulate here corrections made in various appendices of those papers.

[1] Under a grant from the Penrose Fund of the Geological Society of America. The full results of this work will appear elsewhere.

GENUS *CYCLOZYGA* KNIGHT, 1930

In proposing this name (Knight, 1930, p. 19), I neglected to designate a genotype. To repair the omission, I here designate *Cyclozyga mirabilis* Knight as genotype (Knight, 1930, p. 74).

SUB-GENUS *PYRGOZYGA* KNIGHT, 1930

This name proposed by me (Knight, 1930, p. 15) was later (Knight, 1932, p. 202) indicated

seemingly to be a subjective synonym of *Palaeostylus* Mansuy, 1914, and since the latter has priority over *Pseudozyglopleura* Knight, 1930, of which *Pyrgozyga* was regarded as a subgenus, it must be regarded as the nomenclaturally typical subgenus. I have recently been privileged to examine the holotype of *P. popoides* Mansuy, genotype of *Palaeostylus*, and my opinion that *Pyrgozyga* is a close subjective synonym of *Pulaeostylus* previously based on the literature is now confirmed by a comparison of the diplotypes of each.

GENUS *ACLISINA* DEKONINCK, 1881

In 1931 I (Knight, 1931, p. 1 ff.) referred certain forms to *Aclisina* deKoninck. Later (Knight, 1933, p. 57) I pointed out that the valid genotype of *Aclisina* is *A. striatula* (deKoninck) and not *A. pulchra* deKoninck. I can now confirm through a study of the type specimens of *A. striatula* that this form is wholly unrelated to *A. pulchra* and to nearly all of the species commonly referred to *Aclisina* since deKoninck's first use of the name. Hence, I then proposed the genus *Donaldina* (Knight, 1933, p. 57) for those rather numerous species commonly though erroneously referred to *Aclisina*, with *Aclisina grantonensis* Donald as the genotype. All the American Pennsylvanian species referred by me previously to *Aclisina* are referable to *Donaldina*.

GENUS *MACROCHILINA* BAYLE, 1880

Since this genus and the name to designate it had been previously involved in misunderstandings as to its characters and a host of nomenclatural errors, it is unfortunate that in respect to the latter, at least, I added to the confusion in my treatment (Knight, 1931a, p. 181 ff.) by failing to solve the problem of what species exactly is its valid genotype.

It is also unfortunate that the valid genotype, *Buccinum acutum* Sowerby, proves to have the same generic characters as *Soleniscus typicus* Meek and Worthen, genotype of *Soleniscus* Meek and Worthen, and not those of *Buccinites arculatus* Schlotheim which has mistakenly been regarded as the genotype of *Macrochilina*. Basing my concept of *Macrochilina* in 1931 on the group of species with the same generic characters as *B. arculatus* I regarded it as a subgenus of *Soleniscus*. With *B. acutum* as the valid genotype, *Macrochilina* must take a place as a close subjective synonym of *Soleniscus*, while the name *Strobeus* deKoninck, which in 1931 I regarded as a close subjective synonym of *Macrochilina*, must be applied to the group of species that includes *B. arculatus*. I shall redescribe in detail elsewhere the genotype species of these genera and here will concern myself mainly with the nomenclatural questions involved and present a revised taxonomy of the Soleniscinae.

The problem of the genotype of *Macrochilina* is a complex one, and involves two other names, both suppressed prior exact synonyms of *Macrochilina*. These are *Duncania* Bayle, 1879 (not deKoninck, 1874)

and *Macrocheilus* Phillips, 1841 (not Kirby, 1838). The first of these three exact synonyms to be proposed was *Macrocheilus* Phillips; the other two, *Duncania* and *Macrochilina*, both being proposed to replace *Macrocheilus*, preoccupied. *Duncania* itself proved to be an homonym. Since *Macrochilina* and *Duncania* were both proposed as new names for *Macrocheilus*, not as new genera, they are exact, or objective synonyms of it and must have the same genotype as *Macrocheilus*. No species not valid or available for *Macrocheilus* can be valid or available for either of the names proposed to replace it. Thus Bayle's designation of *B. arculatum* as genotype when he proposed the new name *Duncania* depends for its validity as to whether or not it was valid for *Macrocheilus*. As a matter of fact, it was not, as I shall show. Indeed, *B. arculatum*, as I had recognized in my earlier paper, had been designated genotype of *Macrocheilus* by Woodward (1851–56, p. 127) in 1851. King (1850, p. 211) had previously designated *B. breve* Sowerby as genotype. But examination of Phillip's (1841, p. 103) original proposal of *Macrocheilus* shows that both of these two species were doubtfully included by him in his new genus and hence neither is available as genotype for *Macrocheilus*. Since they were not avaiable for *Macrocheilus* they are also not available for the two new generic names proposed by Bayle to replace it, even though Bayle expressly named one of them, *B. arculatum*, as genotype when proposing *Duncania*. The first valid designation of a genotype for *Macrocheilus* (or its two exact synonyms) seems to have been made by Keyes (1889, p. 420) who named *B. acutum* Sowerby (Sowerby, 1827). *B. acutum* was one of three species included by Phillips in *Macrocheilus* without question when he proposed the name and hence, if I am correct that no one had made a valid designation prior to Keyes' action in 1889, *B. acutum* is the valid genotype for *Macrocheilus* Phillips. It is also genotype of *Duncania* Bayle and *Macrochilina* Bayle, since these two names, being proposed as substitutes for *Macrocheilus* are exact, or objective synonyms of it.

For sake of clarity it may be well to recapitulate the nomenclature of the genera of the subfamily Soleniscinae. All the names are here given full generic rank, the distinguishing characters of the genus are briefly given for each name retained, and the nomenclatural synonymy of each is cited.

Family SUBULITIDAE Lindström, 1884

Sub-family SOLENISCINAE Knight, 1931

Genus SOLENISCUS Meek and Worthen, 1860 (Miss.-Penn.)

Genotype, by original designation, *Soleniscus typicus* Meek and Worthen, 1860.

Two folds on the inner lip, the posterior fold the stronger, both folds far forward on the columella, inductura incomplete, form slender.

Subjective synonym of *Soleniscus*.

Macrochilina Bayle, 1880, genotype, by exact synonymy, *Buccinum acutum* Sowerby, 1827.

Exact synonyms of *Macrochilina:* (1) *Macrocheilus* Phillips, 1841 (not Kirby, 1838), genotype, by subsequent designation of Keyes, 1889, *Buccinum acutum* Sowerby, 1827; and (2) *Duncania* Bayle, 1879 (not deKoninck, 1874), genotype, by exact synonymy, *Buccinum acutum* Sowerby, 1827.

Genus STROBEUS deKoninck, 1881 (Dev.-Perm.)

Genotype, by subsequent designation of Cossmann, 1909, *Strobeus ventricosus* deKoninck, 1881.

Two folds on the inner lip, the anterior fold stronger, posterior weak, obscure, located on parietal wall, inductura complete, form slender to robust.

Subjective synonyms of *Strobeus:* (1) *Plectostylus* Conrad 1842, (not Beck, 1837), genotype, by original designation, *Plectostylus hildrethi* Conrad, 1842; and (2) *Sphaerodoma* Keyes, 1889, genotype, by subsequent designation of Girty, 1915, *Stylifer primogenia* Conrad, 1835.

Genus CYLINDRITOPSIS Gemmellaro, 1890 (Penn.-Perm.)

Genotype, by subsequent designation of Cossmann, 1909, *Cylindritopsis ovalis* Gemmellaro, 1890.

Two folds on the inner lip, both folds strongly developed, posterior fold on the parietal wall, inductura complete, form slender to robust.

Genus BULIMORPHA Whitfield, 1882 (Miss.)

Genotype, by subsequent designation of Whitfield, 1882, *Bulimella bulimiformis* Hall, 1858.

A single poorly developed fold far forward on the columellar lip, inductura incomplete, form slender.

Exact synonym of *Bulimorpha: Bulimella* Hall, 1858 (not Pfeiffer, 1854), genotype, by exact synonymy *Bulimella bulliformis* Hall, 1858.

Genus LEPTOPTYGMA Knight, new genus (Penn.)

Genotype, *Auriptygma virginatum* Knight, 1931.

A single very obscure fold rather high on the columellar lip, inductura incomplete, form slender to robust.

GENUS *AURIPTYGMA* PERNER, 1907

My concept (Knight, 1931a, p. 191) of the genotype of this genus was first based wholly on the literature. During the course of my work in Europe, I had the privilege of studying the type specimens of the genotype species, *A. fortior* Barrande mss. Perner, 1907, in the Barrandeum, Národní Museum at Prague, and am forced to conclude that the American Pennsylvanian species that I referred to the genus are not congeneric with it. I shall redescribe and refigure *A. fortior* elsewhere, but in the meantime, it may not be amiss to say that it has a thin sinuous columellar lip much as shown by Perner; it is anomphalous, but has a rather deep false umbilicus; and its columella is sinuous but has no columellar fold. Since the American Pennsylvanian species are seemingly in need of a generic designation, it is in order to propose for them a new genus.

Genus LEPTOPTYGMA Knight, new genus

Genotype, *Leptotygma virgatum* (Knight), 1931 = *Auroptygma virgatum* Knight, 1931. From the Greek λεπτός, slight small, insignificant, and πτύγμα, a fold.

The description of the new genus *Leptotygma* is that given by me for *Auriptygma* (Knight, 1931a, p. 191). Besides the genotype this genus includes *L. substilistriatum* (Knight) and *L. simplex* (Knight) both described and referred to *Auriptygma* in 1931.

GENUS *ACTEONINA* D'ORBIGNY, 1850

In dealing with this genus in 1932 (Knight, 1932, p. 190 ff.) as with *Auriptygma*, I knew the genotype species only from the literature and was led further into error by drawing my concepts of it chiefly from another species, *Scalites fusiformis* deKoninck, 1881, which I regarded as very close to the genotype, *Conus*, or *Chemnitzia carbonaria* deKoninck, 1843. At the time this seemed justified because the genotype species itself was poorly described and figured and deKoninck himself had considered it in 1843 to be conspecific with *C. carbonaria*, the genotype, when he described that species; indeed the types of *S. fusiformis* constituted two of three syntypes of *C. carbonaria*. During my recent work abroad I had the privilege of studying the holotype of *C. carbonaria* in the deKoninck collection in the École des Mines at Paris and while at the Musée royal d'Histoire naturelle at Brussels, I studied also his hypotype of 1881, the only other known specimen of the species. His syntypes of *S. fusiformis* were available to me as well. The two forms *C. carbonaria* and *S. fusiformis* prove to be entirely distinct and unrelated though superficially similar. *C. carbonaria*, the genotype of *Acteonina*, is almost certainly a tectibranch species and the wholly unrelated *S. fusiformis* is congeneric with the American Pennsylvanian and the other Carboniferous species discussed by me in 1932. I shall redescribe and refigure *Acteonina carbonaria* elsewhere, but since the other species in question are now known to be not referable to *Acteonina*, I shall here propose a new genus for their reception.

Genus GIRTYSPIRA Knight, new genus

Genotype, *Girtyspira canaliculata* (Hall) 1857 = *Bulimella canaliculata* Hall, 1858 (p. 29)

The description of the new genus is that given by me for *Acteonina* [*Actaeonina*] (Knight, 1932, p. 193). Besides the genotype I include in the genus the American Pennsylvanian species *G. minuta* (Stevens), and *G. angulifera* (White) and *G. pygmaea* (Weller) the first originally referred to *Loxonema*, the second to *Macrocheilus* and the third to *Bulimorpha;* also the species, other than *Acteonina carbonaria*, referred by deKoninck in 1881 to the genus *Scalites*. All but the third of these species were referred by me to *Acteonina* in 1932 (op. cit.).

GENUS *STROPHOSTYLUS* HALL, 1859

In treating this genus (Knight, 1933, p. 34) I regretfully pointed out what appeared then to be unavoidable truth, that *Strophostylus elegans* Hall, which I also showed to be quite different in its generic characters from what Hall had supposed, was the genotype of *Strophostylus* by virtue of Miller's designation in 1889. I am now pleased to be able to show that Miller's designation of *S. elegans* was invalid and that it must be set aside in favor of Keyes' designation of *S. andrewsi* in 1890. With this latter species as genotype, the name

Strophostylus will retain the significance that Hall originally gave it. In 1933 I was of the opinion that the name *Strophostylus* was first published by Hall in volume 3 of the Paleontology of New York where it was announced as a "new genus" and that that work appeared in 1859 as stated on its title page, an opinion that was seemingly held by all others who have considered the genus. If this had been the fact, *S. elegans* would have been available as genotype and Miller's designation of it in 1889 would have been valid. Since it had priority over Keyes' designation of *S. andrewsi* in the following year it would have had to stand. I was aware that Hall had also published the name *Strophostylus* as new in the 12th Annual Report on the State Cabinet of Natural History and that this report was also dated as published in 1859. But as this report constantly refers to matters as "printed" in volume 3 of the Paleontology of New York it was natural to assume that it appeared subsequent to that work. The truth of the matter seems to be that although volume 3 of the Paleontology *was being printed* during 1859, the printing was not completed and part 1, the text, was not distributed (published) until late in 1860 while part 2, the plates, did not appear until 1861. The 12th Report on the State Cabinet, on the other hand, did appear late in 1859 and a preprint of the first 20 pages or so, including the proposal of name *Strophostylus*, was distributed even earlier in the same year. The evidence for these dates is to be found in several contemporary issues of the American Journal of Science (2d ser., vol. 28, p. 149; vol. 29, p. 453; vol. 31, p. 125). Thus the name *Strophostylus* Hall dates from the 12th Report on the State Cabinet, or from the above mentioned preprint, if that constitutes valid publication, and not from volume 3 of the Paleontology of New York. Only such species were available as genotype as were available on the basis of the original publication of the name. In the original publication of *Strophostylus* in the 12th Annual Report (Hall, 1859, p. 21) the genus is defined and excellent figures of very perfect specimens of two species are given, without specific names, to illustrate the generic characters. Also a list of names included in the genus is given but these names are without exception *nomina nuda* in this, the original publication. All of the specific names in this list are new with one exception and in the case of this one exception, *S. expansus*, the specific name occurs in a new combination with no indication of prior usage. The *nomen nudum*, *S. elegans*, heads this list, which also includes *S. transversus* and *S. andrewsi* as *nomina nuda* though specimens that, on the basis of later publication, can be shown to be the holotypes of these last two species are figured on the same page. There is no indication whatever in the original publication that "*S. expansus*" is *Platyceras expansus* Conrad, 1841, or that the names *S. transversus* or *S. andrewsi* apply to the specimens figured.

Since *nomina nuda* are naked

names, names for nothing, and therefore not names at all from the point of view of technical nomenclature and, since all the names listed in the original publication in the genus *Strophostylus* were *nomina nuda* in that publication, the question as to what species are available as genotypes falls under one of the categories covered in Opinion 46 of the International Commission on Zoological Nomenclature (Smithsonian Inst., Publ. 2060, p. 104 ff.) dealing with the status of genera for which no species was distinctly named in the original publication.[2] Opinion 46 states that

> In genera published without mention, by name, of any species no species is available as genotype unless it can be recognized from the original generic publication; . . . .

The only two species that can be recognized from the original publication of the genus *Strophostylus* are the two that are figured without being named in that publication. Hence, these two species, whatever names may have been validated for them later, and no other species, were available as genotypes. Later, in Paleontology of New York, volume 3, the names *S. transversus* Hall and *S. andrewsi* Hall were validated for the two species in question. Of course the other *nomina nuda* listed in the original publication were validated at the same time, but they were neither valid as names nor recognizable in the zoological sense in the original publication.

From the above, it follows that *S. elegans* Hall was not available as genotype and that Miller's designation of it in 1889 has no validity. It likewise follows that *S. andrewsi* was available and that Keyes' designation of it in 1890 was valid, and, being the first valid designation of a genotype for *Strophostylus*, it must stand.

With *S. andrewsi* Hall as genotype, the name *Strophostylus* Hall retains its original significance and not that which I applied to it in 1933 where I considered it as a subjective synonym of *Callonema* Hall (not Conrad) = *Elasmonema* Fischer, in the Trochoturbinidae. *S. elegans* Hall, however, is not congeneric with *S. andrewsi*, as I showed in 1933, and must now be known as *Elasmonema elegans* (Hall).

SUBGENUS *ANEMATINA* KNIGHT, 1933

With the name *Strophostylus* returned to its original significance, *Anematina*, originally proposed (Knight, 1933, p. 36) as a subgenus of *Strophostylus*, becomes a subgenus of *Elasmonema* Fischer.

GENUS *FLEMINGIA* DEKONINCK, 1881

While in Europe, I had the privilege of studying the type specimens of the genotype, *Trochella prisca* M'Coy, deposited in the National Museum of Ireland at Dublin. On the basis of the characters of its genotype *Flemingia* is only remotely

[2] In all fairness it should be stated that the question of the availability as genotypes of *nomina nuda* that are validated as names of actual species in some later publication, has never been passed upon by the Commission, but the conclusions stated above appear to be in full harmony with the general treatment of *nomina nuda* by the Rules and Opinions.

related to *Elasmonema* or *Anematina* and consequently it is to be removed from subjective synonymy of the latter where I placed it tentatively (Knight, 1933, p. 37). Since *Flemingia* deKoninck, 1881, is an homonym of *Flemingia* Johnston, 1845, and since it seems to have no valid synonym, I now propose the new name ***Flemingella*** to replace it as its exact synonym.

GENUS *GLYPTOBASIS* DEKONINCK, 1881

I have pointed out (Knight, 1933, p. 37) that *Glyptobasis* deKoninck, 1881, is an homonym (*Glyptobasis* McLachlan, 1871) and have referred it tentatively to subjective synonymy with *Anematina*. No genotype was designated or indicated by deKoninck and since none has been designated since, I shall now fix the name by designating *Glyptobasis conica* deKoninck, 1881. I have studied the types of *G. conica*, which are in the Musée royal d'Histoire naturelle at Brussels, and find that it is conspecific with *Cerithioides telescopium* Haughton, 1859, the genotype of *Cerithioides* Haughton, 1859, the types of which I have also studied in the British Museum (Natural History) in London. *Glyptobasis* deKoninck is thus a subjective exact synonym of *Cerithioides* and as such should not be replaced by a new name.

I shall not deal further with *Glyptobasis* (= *Cerithioides*) here, other than to point out that it has a selenizone (overlooked by deKoninck) and is wholly unrelated to *Anematina*.

GENERA *ROTELLINA* DEKONINCK, *PYCNOMPHALUS* LINDSTRÖM, AND *ANTIROTELLA* COSSMANN

All three of these genera were placed by me (Knight, 1933, p. 42) as subjective synonyms of *Anomphalus* Meek and Worthen. My understanding of the first two was based wholly on the literature, but in the case of *Antirotella* I had access to authentic specimens of the genotype species. During my work abroad I was able to see the type specimens of the genotype species of all three of them and for the present, at least, continue to regard *Pycnomphalus* and *Antirotella* as subjective synonyms of *Anomphalus*. *Rotellina planorbiformis* deKoninck, the genotype of *Rotellina*, is a most remarkable shell with a deep sinus and narrow slit close to the upper suture and resembles *Anomphalus* only superficially. I shall describe it in detail elsewhere. *Rotellina* must, of course, be removed from the synonymy of *Anomphalus*.

In discussing the generic name, *Rotellina* deKoninck, 1881, I (Knight, 1933, p. 43 footnote) took the stand that it was not preoccupied by the name *Rotellina* cited by Agassiz in his Nomenclator Zoologicus from Serres, 1836, on the grounds that the name attributed to Serres in 1835 was actually the vernacular name "Rotelline" and that the latter for that and other reasons was not a valid name in the sense of the Rules. In taking this stand I entirely overlooked what now appears perfectly obvious, namely that though

the name "Rotelline" is indeed invalid, the name *Rotellina* Agassiz, 1846 (p. 10) is not. This latter name thus does preoccupy *Rotellina* deKoninck and renders it an invalid homonym. In the same discussion (op. cit.) I suggested that the "Rotelline," which must be taken as the nomenclatural genotype of *Rotellina* Agassiz, was probably a Bacterium, and hence was more likely botanical than a zoological name. In the implications I drew from this, I was again in error for Agassiz considered the "Polygastrica," in which he classified the genus as being wholly composed of animals, and Article I of the International Rules provides that "if an organism is transferred from the animal to the vegetable kingdom its *names retain their zoological status*" (the italics are mine). The name *Rotellina* deKoninck must, therefore, be suppressed as an homonym of *Rotellina* Agassiz, 1846; and I propose the new name ***Rhaphischisma*** (Greek ῥαφη = suture; σχίσμα = that which is cloven) to replace it.

GENUS *ANGYOMPHALUS* COSSMANN

This genus I (Knight, 1933, p. 45) attempted to interpret on the basis of its genotype, *Raphistoma radians* deKoninck, as known in the literature and my conclusions as to its characters were very far from the truth. In Europe I was able to study the primary types of the genotype in the École des Mines at Paris and deKoninck's hypotypes of 1881 in the Musée royal d'Histoire naturelle at Brussels. I shall redescribe this species elsewhere and for the present it will suffice to say it is a pleurotomarian, very similar in all respects to the more lenticular of the American Pennsylvanian species of *Trepospira* except that the umbilicus is not plugged by callus.

My findings in respect to the true characters of *Angyomphalus* leaves the two American Pennsylvanian species I referred to it without a genus. Both were originally described as *Naticopsis* though they definitely have nothing in common with the species of that genus. *Naticopsis monilifera* White has been referred to *Pleurotomaria*, but with little more justification than to *Naticopsis*. In respect to the rather deep sinus rather high in the outer lip and the subglobular form, they suggest *Platyschisma* M'Coy, but their anomphalous or possibly cryptomphalous base and subsutural nodes seem to bar them from that genus. Indeed it seems impossible to refer them with any degree of certainty to any described genus, and it thus seems necessary to erect a new one for them.

While this paper was being prepared I had occasion to write Dr. George H. Girty of the U. S. Geological Survey of my findings and intentions in respect to this proposed new genus and was pleased to learn from him that he had had similar intentions for some time and had intended proposing the name *Colpites* for it. It, therefore, gives me pleasure to employ for the genus Doctor Girty's manuscript name and thus have him share with me in the responsibility of proposing it.

Genus COLPITES Girty mss., Knight, new genus.

Genotype, *Naticopsis monilifera* White, 1880 (p. 168).

Moderately small anomphalous or cryptomphalous, subglobular gastropods with somewhat thickened inner lip, low spire, rather numerous whorls, a row of subtural nodes, and a moderately deep sinus in the upper part of the outer lip; without a selenizone.

It will be noted from this diagnosis that my previous scepticism (Knight, 1933, p. 46) in respect to the actuality of the sinus in the outer lip of *C. monolifera* (White) has been dispelled. Mr. Ralph E. King of the University of Texas was good enough to lend me an excellent specimen from the Texas Bureau of Economic Geology collections that showed this character clearly, so that I have no longer any doubt on the point. Neither Sayre's nor my specimens of *C. minutus* (Sayre) showed a sinus, but the surface of Sayre's specimen showed no growth lines whatever, while my specimens were both somewhat corroded. None had well preserved outer lips. Besides the two species mentioned above, I am inclined to refer to the genus, though not without some doubt, the rather imperfectly known *Turbo tiara* of Sowerby.

ISONEMA DEPRESSUM MEEK AND WORTHEN

As I have pointed out (Knight, 1933, p. 44) *Isonema depressum* Meek and Worthen, 1866, and *Isonema humile* Meek, 1872, are synonyms, an opinion that has been strengthened by the study of further specimens. I was unaware at the time that Keyes in 1889 had placed *I. depressum* in the genus *Naticopsis*, and finding the trivial name preoccupied in that genus suppressed it and proposed the new name *linearis* to replace it. Now, since a name once suppressed because of homonymy may not be revived, even though the species is subsequently removed to another genus, the name that should properly be applied to the species is *Isonema humile*, a subjective synonym that has several years priority over the exact synonym proposed by Keyes. The synonymy of the species in so far as it is significant to the point at issue is as follows:

Isonema humile Meek, 1872
Isonema depressum Meek and Worthen, 1866
Naticopsis linearis Keyes, 1889, new name for *N. depressum* (Meek and Worthen), 1866 = *I. depressum* Meek and Worthen, 1866, not *Naticopsis depressa* Winchell, 1864.

GENUS *NATICODON* DE RYCKHOLT

I have had an opportunity to examine what are seemingly de Ryckholt's type specimens of *N. globosa* de Ryckholt in the Musée royal d'Histoire naturelle at Brussels and no longer agree with deKoninck, as I did earlier (Knight, 1933a, p. 362), in thinking that de Ryckholt was in error in describing a tooth on the columella of this species well within the aperture. I am prepared to affirm that there is actually a well developed and unmistakable tooth somewhat as described by de Ryckholt in 1847, but I am not at the moment prepared to say that the name *Naticodon* should therefore be removed from the synonymy of

Naticopsis. Indeed it seems best at present to maintain the synonymy, at least until an opportunity arises to make a comprehensive study of the Paleozoic Neritidae.

NATICOPSIS WORTHENI KNIGHT, 1933 (not *N. wortheni* Weller, 1916)

I have proposed (Knight, 1934a, p. 446) the name *N. wortheniana* Knight to correct the homonymy.

GENUS *ORTHONYCHIA* HALL, 1843

Platyceras subrectum Hall is the genotype of *Orthonychia* (Knight, 1934, p. 147) but on other grounds than those stated by me. Under Opinion 46 of the International Commission of Zoological Nomenclature, when a generic name is proposed without any species being included in it by name, only such species are available as genotype on the basis of the original publication as can be recognized on the basis of that publication. In the original publication of *Orthonychia* the generic name was applied to a single species, a specimen of which was figured on the same page without a specific name. This species is figured sufficiently well to be recognizable and is, therefore, the genotype by monotypy. In 1859 the name *Platyceras subrectum* was proposed by Hall for the species in question, the same specimen that was figured in 1843 being refigured under this specific name.

GENUS *DIAPHOROSTOMA* FISHER

On grounds that will be discussed later in these notes, I am now of the opinion that the name *Platyostoma* Conrad, 1842, may not be validly emended to *Platystoma* and that it, therefore, is not an homonym of prior usages of *Platystoma* and may not be validly suppressed in favor of its subsequent exact synonym *Diaphorostoma* Fisher, 1887. This is a reversal of my earlier opinion (Knight, 1934, p. 148), when I erroneously accepted and justified the emendation of *Platyostoma*, its suppression as an homonym, and the employment of *Diaphorostoma* in its place.

GENUS *HELICTOSTYLUS* KNIGHT

This genus was proposed by me (Knight, 1934, p. 148) with *Strophostylus andrewsi* Hall as the genotype. Since I have been able to show above that this species and not *S. elegans* Hall is also the valid genotype of *Strophostylus* Hall, 1859, the name *Helictostylus* is no longer necessary and will find its place as an exact synonym of Hall's earlier name.

The American Pennsylvanian species described by me (Knight, 1934, p. 165) becomes *Strophostylus girtyi* (Newell mss., Knight), 1934.

EMENDATION OF NAMES

Several of my very good friends have maintained to me in personal communications that I have at times gone beyond the provisions of the International Rules of Zoological Nomenclature in the matter of emendation of improperly formed names of genera and species. A careful restudy of Article 19 of the Rules and of the full texts of the Opinions of the

Commission bearing on emendations has convinced me that I have somewhat overstepped the very rigid provisions of the Rules in respect to emendations.

Article 19 of the Rules provides that "The original orthography of a name is to be preserved unless an error of transcription, a *lapsus calami*, or a typographical error is evident." Here we have two very important points that are stressed in the Opinions; only the *three types of errors cited* are subject to emendation at all; and such errors must be *evident*. The full text of Opinion 26 makes it clear also that "to be 'evident,' in the sense of this article, involves the presence (in the original publication) of clear evidence that the spelling in question is erroneous." The term "erroneous" here definitely refers to the three categories of errors mentioned in Article 19. No other types of errors are emendable no matter how evident. Opinions 34 and 36 in the full text are most illuminating also as illustrating the strict interpretation of the word "evident."

It seems perfectly clear that whatever corrections are permissible should be made at the earliest opportunity, as only in this way will the attainment of ultimate stability be forwarded. An unemended but emendible name is in a state of instability; so is an illegally emended name. The first consideration led me to make some emendations that prove to be illegal, i.e., contrary to the letter and spirit of the Rules; the second leads me now to review all my emendations of the orthography of names of genera and species, and of emendations of such names by others previously accepted by me, in the light of a careful restudy of the whole situation.

Acteonina d'Orbigny.—The name was originally proposed in this form; its derivation is obvious from the original publication as from *Acteon* Montfort with the diminutive termination *-ina*. While both *Acteon* and *Acteonina* are often written with an *ae* as *Actaeon* and *Actaeonina*, neither appear to be emendable under Article 19 of the Rules.

Trachydomia Meek and Worthen.—I emended (Knight, 1933a, p. 363) this name to *Trachydoma* on the grounds that the name could not properly be rendered as it was by its authors from the derivation given. I can see no reason to modify my previous contention that the name was improperly formed, but since Meek and Worthen obviously intended to write it as they did and since no error in transcription, *lapsus calami*, or typographical error is evident, I must now recognize that my emendation was not in order. The original orthography must be retained.

Naticopsis ventricosa (Norwood and Pratten).—In view of the facts and arguments set forth by me (Knight, 1933a, p. 371) Meek and Worthen's emendation of Norwood and Pratten's original rendition of the trivial name of this species seems to have been in order and should stand.

Straparolus Montfort.—This is the original orthography of the name. Although it has become customary

to render it *Straparollus*, I know of no justification for the emendation.

Platyostoma Conrad.—I have previously (Knight, 1934, p. 148) followed the current fashion in regarding *Platyostoma* as validly emended to *Platystoma* and in its emended form an homonym of several prior usages of the name. But no "error in transcription, *lapsus calami*, or typographical error is evident" in Conrad's original proposal of the name. True, the name is badly formed, but, granting that, there can be no doubt that Conrad intended to write it just as he did. How he should have written the name if he had given the matter more thought is beside the point. The name, therefore, is not subject to emendation and is not an homonym of *Platystoma* of several earlier authors. *Diaphorostoma* Fischer is thus to be suppressed as a subsequent exact synonym of a prior valid name.

Since the nomenclatural and generic changes proposed and discussed in this paper result in extensive and in some instances complicated changes of the names used in the former papers cited, it may help clarify matters to cite an example of the change necessary in each generic or subgeneric group for species described or illustrated. A list of all the nomenclatural changes required for every species would be very long and would serve no purpose that a single example from each combination will not serve. I shall not cite especially changes in orthography nor shall I cite species mentioned but neither described nor illustrated. This list will serve those who do not care to study and apply in detail the results of the various discussions and conclusions in the foregoing part of this paper. The names of each paper will be taken up separately and in order of publication.

Names previously employed	Revised names
(Knight, 1930)	(Knight, This paper)
Pseudozygopleura (*Pseudozygopleura*) *semicostata* (Meek)	*Palaeostylus* (*Pseudozygopleura*) *semicostatus* (Meek)
Pseudozyglopleura (*Pyrgozyga*) *cylindrata* Knight	*Palaeostylus* (*Palaeostylus*) *cylindratus* (Knight)
Pseudozygopleura (*Stephanozyga*) *subnodosa* Knight	*Palaeostylus* (*Stephanozyga*) *subnodosus* (Knight)
Pseudozyglopleura (*Leptozyga*) *minuta* Knight	*Palaeostylus* (*Leptozyga*) *minutus* (Knight)
Helminthozyga vermicula Knight	No change
Hemizyga (*Plocezyga*) *corona* Knight	No change
Hemizyga (*Hemizyga*) *inflata* Knight	No change
Hemizyga (*Hyphantozyga*) *gracilis* Knight	No change
Cyclozyga mirabilis Knight	No change
(Knight, 1931)	
Aclisina stevensana (Meek and Worthen)	*Donaldina stevensana* (Meek and Worthen)
Streptacis whitfieldi Meek	No change
(Knight, 1931a)	

NAMES PREVIOUSLY EMPLOYED (Knight, 1930)	REVISED NAMES (Knight, This paper)
Soleniscus (*Soleniscus*) *typicus* Meek and Worthen	*Soleniscus typicus* Meek and Worthen
Soleniscus (*Macrochilina*) *primogenius* (Conrad)	*Strobeus primogenius* (Conrad)
Soleniscus (*Cylindritopsis*) *vaningeni* Knight	*Cylindritopsis vaningeni* (Knight)
Auriptygma virgatum Knight	*Leptoptygma virgatum* (Knight)
Soleniscus (*Bulimorpha*) *bulimiformis* (Hall)	*Bulimorpha bulimiformis* (Hall)
Auriptygma fortier (Barrande) Perner (Knight, 1932)	*Auriptygma fortior*, Barrande mss., Perner
Meekospira peracuta (Meek and Worthen)	No change
Actaeonina minuta (Stevens) (Knight, 1933)	*Girtyspira minuta* (Stevens)
Strophostylus (*Anematina*) *proutanus* (Hall)	*Elasmonema* (*Anematina*) *proutanum* (Hall)
Strophostylus (*Strophostylus*) *bellatulus* (Hall)	*Elasmanema* (*Elasmanema*) *bellatulum* (Hall)
Angyomphalus minutus (Sayre)	*Colpites minutus* (Sayre)
Angyomphalus radians deKoninck	No change
Microdoma conicum Meek and Worthen	No change
Yunnania subsinuata (Meek and Worthen)	No change
Rhabdotocochlis rugata Knight	No change
Araeonema virgatum Knight	No change
Eucochlis perminuta Knight	No change
Anomphalus umbilicatus Knight	No change
Isonema depressum Meek and Worthen	*Isonema humile* Meek
Anomphalus planorbiformis (deKoninck) (Knight, 1933a)	*Rhaphischisma planorbiformis* (deKoninck)
Naticopsis wortheni Knight	*Naticospsis wortheniana* Knight
Trachydoma nodosum Meek and Worthen	*Trachydomia nodosa* Meek and Worthen
Turbonitella biserialis (Phillips)	No change
Natiria americana (Girty) (Knight, 1934)	No change
Straparollus (*Straparollus*) *dionysii*? Montfort	*Straparolus* (*Straparolus*) *dionysii* Montfort
Straparollus (*Euomphalus*) *catillus* (Sowerby)	*Straparolus* (*Euomphalus*) *catillus* (Martin), 1793[3]
Orthonychia parva (Swallow)	No change
Helictostylus girtyi Newell mss. (Knight, 1934a)	*Strophostylus girtyi* (Newell mss., Knight)
Orthonema salteri Meek and Worthen	*Orthonema salteri* (Meek and Worthen)

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[3] I have learned that this species was first described by Martin in 1793 as *Helix catillus*. The name in this publication, unknown to me in 1934, is valid.

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J. BROOKES KNIGHT, PRINCETON UNIVERSITY, PRINCETON, N. J. MANUSCRIPT RECEIVED BY THE EDITOR, JUNE 1, 1936.

REVIEW

HISTORICAL GEOLOGY OF THE ANTILLEAN-CARIBBEAN REGION, Charles Schuchert, John Wiley and Sons, Inc., New York (1935), 811 pp., 107 figs. 6×9 inches, cloth, price, $10.00.

This 811-page tome dealing with the stratigraphy and geologic history of the lands bordering the Gulf of Mexico and the Caribbean Sea is the first of a larger proposed work entitled *A Historical Geology of North America*. It is an attempt to assemble the considerable but widely scattered geological information on these lands and to synthesize it into a picture of the geological development of the region as a whole. The author admittedly has little first-hand information on much of the territory with which he deals, but his long interest in this region, his acquaintance with the literature, and his broad experience in the fields of historical geology and paleogeography make his book a most welcome contribution to the geology of the Caribbean region.

The book is divided into four sections, of which the "Introduction and Summary" occupies 56 pages. This section is an introduction and at the same time contains the author's conclusions and generalizations. It includes an appreciation of the earlier workers on the geology of the Caribbean region and brief discussions of the geological sub-regions, the major geological features, the principal periods of diastrophism, and the paleogeography. Section II is entitled "The Three Middle American Basins" and deals with the Caribbean and Antillean seas and the Gulf of Mexico. Section III is a discussion of biogeography and paleo-biogeography.

Section IV, "The Lands," occupies the bulk of the volume (650 pages). In this section the author treats in considerable detail the stratigraphy and to some extent the physiography and structure of the seven geological sub-regions into which he has divided the greater Antillean-Caribbean region. These are: (1) Mexico, 98 pp.; (2) the Gulf Coastal Plain of the United States, 84 pp.; (3) nuclear Central America including Chiapas, Guatemala, Honduras, and northern Nicaragua, and its young foreland comprising Tehuantepec, Tabasco, Campeche and Yucatan, 72 pp.; (4) the Antilles and their Bahaman foreland, 150 pp.; (5) the young isthmian link connecting Central and South America: Panama, Costa Rica, and southern Nicaragua, 58 pp.; (6) northern South America, including Colombia, Venezuela, Trinidad, Barbados, and Tobago, 104 pp.; and (7) the oceanic islands, Bermuda and the Caribbees, 38 pp.

Following the discussions of each of the regions are selected bibliographies occupying from 5 to 10 pages each. These are by no means complete but include most of the important publications. The book is profusely illustrated with more than a hundred geologic and geographic maps, most of which are taken from previous publications. Of particular value are the author's sixteen paleogeographic maps showing the distribution of land and sea at as many different epochs between Middle Pennsylvanian and Pleistocene time. There are numerous correlation charts for local areas and large charts for each of the principal subregions. Interspersed throughout the book are plates with photographs of many of the pioneers of Caribbean geology. The index, a feature of considerable importance in a book of this size and nature, occupies 42 pages.

The historical geology of the Caribbean region as treated by Professor Schuchert is essentially the history of eight major structural and paleogeographic features which exist or have existed in this portion of the world. These are as follows: (1) The Antillean geanticline or protaxis, extending in a broad arc from southwestern Mexico through the middle of Central America to Jamaica, Hispaniola, and Puerto

Rico. (2) The Caribbean Mediterranean, a suboceanic basin between the Antillean protaxis and northern South America. (3) The now largely foundered borderland of Paria which formed the southern frame of the Caribbean basin and included Barbados, Tobago, Trinidad, and the Venezuelan coastal islands. (4) The Antillean geosyncline, just north of the geanticline and extending from southeastern Mexico through northern Central America to Cuba and northernmost Hispaniola and including the area of the existing Antillean Sea which is separated from the larger Caribbean basin by the submarine ridge connecting Honduras and Jamaica. (5) The Gulf of Mexico plate, a neutral foreland to the north of the Antillean geosyncline which began to break down in the Mesozoic and has now sunk to the depths of the present Gulf. (6) The Caribbee volcanic arc, consisting of the islands of the Lesser Antilles. (7) The "volcanic" Bahamas, assumed to have a volcanic base similar to Bermuda. (8) The Panama-Costa Rica land bridge, which has intermittently connected the two continents since Late Mesozoic time.

The author's analysis of the diastrophic history of the lands bordering or within the Caribbean Sea and the Gulf of Mexico shows "at least five and possibly eleven times of diastrophic movement." These are as follows: (?) Late Proterozoic, (?) Middle Paleozoic, Late Paleozoic, (?) Late Triassic, (?) Late Jurassic, Late Lower Cretaceous and Late Cretaceous, late Eocene, early and late Oligocene, and late Miocene to Pleistocene. Of these movements, those of the Late Paleozoic and Late Cretaceous are called orogenic revolutions, while that of the late Miocene to Pleistocene is termed an epeirogenic revolution.

The author emphasizes repeatedly his conviction that there is no fundamental connection between the Rocky Mountain system of North America and the Andean system of South America, either through Central America or through the Antilles. Between these two dominantly north-south trending systems lies the ancient Caribbean basin and the east-west trending Antillean orogenic system consisting of northern Central America and the Greater Antilles on the north and the Venezuelan coastal ranges on the south. The Panama-Costa Rica isthmus and the Caribbee (Lesser Antilles) island arc are considered to be superficial connections due largely to Cenozoic volcanism. There are perhaps few today who would support von Humboldt's early view that the Andes and Rockies are connected through Central America; but Suess' hypothesis, that the Rocky Mountain system swings eastward through northern Central America and the greater Antilles and then curves southward through the arc of the Lesser Antilles to join the Caribbean Range of Venezuela and the Andes, is certainly not without supporters. Rutten[1] has recently again presented arguments in favor of this hypothesis.

The author's views regarding the origin of the three middle American basins, discussed in Section II, also have been disputed. He believes that the Caribbean Sea has endured since at least Early Paleozoic time and that the Gulf of Mexico was developed from an older broad gentle plate-like basin by subsidence which began in Middle Cretaceous time. Rutten,[2] on the other hand, considers all of these basins as of post-Cretaceous origin.

In Section III the author reviews biologic and paleontologic evidence bearing on the paleogeography of the Caribbean region. He concludes that there is definite evidence of land migration between Central America and the Greater Antilles and that connection between these lands seems to have existed principally in the Eocene and in Miocene and early Pliocene time. On the other

[1] Rutten, L., Über den Antillenbogen: *K. Akad. Wetensch. Amsterdam, Verh.*, vol. 38, no. 10, pp. 1046–1058, 1935.

[2] Rutten, L., Alte Land- und Meeresverbindungen in West-Indien und Zentralamerika: *Geol. Rundschau*, Band 26, pp. 65–94, 1935.

hand, he sees no biologic evidence of a land bridge uniting the Caribbee Islands with either the Greater Antilles or South America. The life of these islands is Venezuelan but probably of waif origin. Connection between North and South America by way of the Panama-Costa Rica isthmus was probably established during Late Cretaceous to early Eocene time, was broken during most of the interval from upper Eocene to middle Miocene time inclusive, and was finally restored in Pliocene time.

The geology of the individual land areas of the Caribbean region (Part IV) is largely a compendium of the published information which has appeared in the last forty years. The immense number of these publications was brought home to the reviewer some time ago during the preparation of a bibliography for a part of this region which soon included several thousand titles in English, German, French, Dutch, Spanish, and Italian. Since the author of the book has accepted the literature "at face value until it was contradicted by later work or not borne out by interregional correlations," it is only natural that some poor work has been included with the good. Moreover, the great bulk and variety of the available material make it difficult for any one person to digest it all satisfactorily.

This last section of the book provides a good survey of the published information on the geology of each of the subregions which for outsiders will no doubt seem quite adequate. Geologists with intimate first-hand knowledge of these regions will always find the treatment of their own region slightly unsatisfactory, however. In this connection it should be said that the value of the work is greatly increased by the fact that many of the chapters have been read, previous to publication, by geologists particularly acquainted with the regions concerned. Thus, the discussion of the Gulf Coastal Plain has been read and corrected by L. W. Stephenson, C. W. Cooke, and Julia A. Gardner; parts of the chapter on Guatemala were read by Karl Sapper the section on Honduras was read by Charles Weaver; that on Cuba by R. E. Dickerson; and that on Colombia by J. T. Duce, F. B. Notestein, and R. E. King. The section on Panama-Costa Rica was not only read but also partially written by A. A. Olsson and R. A. Terry.

The book is somewhat loosely put together and frequent repetition has made it longer than necessary. It is not without some minor errors which might have been avoided. Thus, in the chapter on Venezuela, which was of particular interest to the reviewer, the upper Eocene age of the Pauji shale is correctly given on page 686 but on page 622 the formation is placed in the lower Oligocene. On page 682, *Corbula comparana* is an obvious error for *Corbicula comparana*. And on page 685 it is stated that the Boca de Serpiente, San Pedro, and Rio Caus formations with *Orthophragmina georgiana* and *Helicolepidina spiralis* are upper and middle Oligocene! Recent papers of major importance by Rutsch, Schurmann, and Rutten are not mentioned. Unfortunately, a most recent paper by Senn[3] probably reached this country too late to be included.

Professor Schuchert's book will be of great service to anyone doing geological work in this region, not only for the author's own ideas but also because it summarizes so much of the literature to which access in these countries is difficult or impossible. However, a volume of this sort is valuable not only as a reference book and source of information but also as a basis for criticism. It is a tangible statement of ideas with which others may compare and contrast their own information and opinions. It will undoubtedly help to crystallize the thoughts of many workers on the historical geology of the Antillean-Caribbean region.

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[3] Senn, A., Die stratigraphische Verbreitung der tertiaren Orbitoiden: *Eclogae Geol. Helvetiae*, vol. 28, pp. 51–114, 1935.

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